USING AN ADAPTIVE LOGISTICS NETWORK IN AFRICA: HOW MUCH AND HOW FAR

GRADUATE RESEARCH PAPER

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AFIT/IMO/ENS/09-16

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Abstract

Since the 1990s, Africa has grown in strategic importance to the United States due to oil, trade, armed conflict, terrorism, and HIV/AIDS. As a result, the United States created Africa Command (AFRICOM), a new military geographic combatant command. AFRICOM's mission is to aid African development and promote regional security. As part of its mission, AFRICOM will need to move cargo throughout Africa, which has the least developed transportation infrastructure in the world. Coupled with the poor infrastructure issue, AFRICOM only has one base on the continent and extremely limited dedicated transport assets. AFRICOM logistics planners' solution to this problem is the creation of an Adaptive Logistics Network (ALN) that can expand or contract as necessary using in place transportation assets owned by African businesses. However, logistics planners still must know how much cargo can be pushed through individual airports, and once there, how far that cargo can be moved in a given amount of time. Two mobility modeling simulations, the Airport Simulation Tool (AST) and the Enhanced Logistics Intra-theater Support Tool (ELIST), are detailed by this study showing how they can assist in estimating the answers to how much and how far. The models' capabilities and limitations are explored, and recommendations are made to assist AFRICOM in the use of these two tools to aid AFRICOM logistics planning and forecasting.

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2LT Erik Mirandette and Adrien Finnan gave me first hand insight on the African road system through their extensive travels in Africa. Erik's book, *The Only Road North*, sparked my initial interest in Africa as a topic.

Finally, my wife, Nikki, gave up countless hours of family time so that I could do this research and she was also my editor. I owe her thanks for that and so much more.

Tom R. Ulmer

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USING AN ADAPTIVE LOGISTICS NETWORK IN AFRICA: HOW MUCH AND HOW FAR

I. Introduction

Background, Motivation, and Problem Statement

Through much of the last two decades, the continent of Africa has only slightly been of any strategic importance to the United States. However, starting in the 1990s, the tide began to change and Africa has since steadily become more important to both the United States as a whole as well as the U.S. military. Africa's oil reserves, rising global trade with Africa, armed conflicts within Africa, Africa's center as a breeding ground for terrorism, and HIV/Aids, have heightened Africa's strategic importance to the point that in 2008, the United States created Africa Command (AFRICOM), the sixth geographic combatant command.

Despite its rising strategic importance, the African transportation infrastructure has not kept pace with Africa's growth. While 90% of Africa's inter-urban transport is achieved via road, only one third of its 1.2 million mile road network is paved, and that one third that is paved is often not well maintained (Diarra, 2008). Africa on the whole does not allocate enough money to improve or further develop its road network. Africa's railway system was mostly built during the colonial era. The bulk of Africa's railroad network is in South Africa, and several countries have no railroads at all. African airports generally have deteriorating runways, obsolete air traffic control equipment, and lack modern facilities and cargo handling equipment. The infrastructure is at its worst in Africa's landlocked countries, and these countries also are the poorest in Africa.

AFRICOM was created because the emergence of Africa and its strategic importance was putting a large strain on the three commands that previously had Africa in their area of responsibility (AOR). European Command and Central Command especially were dealing with African conflicts, anti-terrorism, and humanitarian issues. AFRICOM's focus is to provide aid in African development and create stability throughout the continent. However, AFRICOM's only military base on the continent is Marine Camp Lemonier in Djibouti. While AFRICOM wants to keep a small footprint on the continent, it must have some additional support. To provide this support, AFRICOM is relying on small outposts spread throughout Africa called cooperative security locations (CSLs). These locations have either pre-positioned supplies or equipment (or both), little or no permanent U.S. presence, and are maintained by either contractors or host nation support. CSLs effectively allow AFRICOM to have a network throughout the continent while maintaining a minimal U.S. presence.

Maintaining a minimal presence has a cost though for AFRICOM's Deployment and Distribution Operations Center (DDOC), which is in charge of logistical moves throughout the continent. Without permanent transportation assets, the DDOC has to think outside the box to move cargo throughout the continent. The theoretical tool they have created to aid their logistics problem is called an Adaptive Logistics Network (ALN). The theory behind an ALN is to use transportation resources already available within Africa (via local freight hauling businesses) and contract them when necessary for the movement of cargo. This network could shrink or expand as necessary and cover the entire continent without needing additional military transportation resources. This would also stimulate the African economy by providing business opportunities for the transportation sector.

The ALN concept is under development now for use in AFRICOM. However, the key question that still remains is will it work in Africa where the transportation infrastructure is rudimentary? As AFRICOM grows, it will need to develop plans for operations within Africa. However, how can it do this when uncertainties exist pertaining to cargo movement and arrival? Clearly, AFRICOM needs a tool to aid them in estimating cargo flow throughout the continent.

Research Objectives & Research Questions

This research seeks to answer two questions proposed by AFRICOM's DDOC. The first question is to look at an airport and determine how much cargo throughput that airport can support. Sending multiple aircraft to a location when that airport does not have supporting infrastructure such as parking spaces, fueling capabilities, material handling equipment, or cargo storage space is futile. AFRICOM cannot afford to over saturate an airport so that flights effectively need to be turned back because they cannot be supported.

The second research question is; once the cargo is at an African location, how far can it be moved in a certain amount of time? Military deployments operate off of plans that specify when equipment and supplies must arrive at their destination. However, with AFRICOM's rudimentary transportation infrastructure, how can planners realistically forecast if the required cargo will arrive on time? And what can planners do to set realistic transport time frames right from the start?

The objective of this research is to show that two mobility models are already capable of helping AFRICOM answer these questions, and to detail how they can be used to answer them. To answer the airport throughput question, a subset of the Arrival Port of Debarkation (APOD) model called the Airport Simulation Tool (AST) can detail how many aircraft an airports infrastructure can support. By knowing the number of aircraft an airport can support, then the amount of cargo throughput can be estimated. To answer how far the cargo can be moved in a certain time, the Enhanced Logistics Intra-theater Support Tool (ELIST) can simulate the execution of a cargo movement plan and detail if cargo arrives on time, what the optimal route is, and what the constraints on the system are. Together, the use of these two models provides AFRICOM with the tools it needs to both plan and forecast logistics movements within Africa.

Research Focus

The throughput portion of this research will focus on three airports selected by AFRICOM: Dakar, Senegal; Entebbe, Uganda; and Mombasa, Kenya. These three airports were part of a 2006 EUCOM study that measured their capabilities using AST. The cargo movement portion of the study will focus on an unclassified demonstration and training scenario in Tunisia. The Tunisia plan, assets, and network are all preloaded as part of the basic ELIST software. Other locations in Africa are available for ELIST, but they are classified in nature.

Methodology

The AST portion of the research will focus on the results from the “U.S. EUCOM Airfield Throughput Analysis Study for Strategic Airlift” written in 2006 by Drabek and others. All three airports requested by AFRICOM were covered in this study. The

ELIST portion of the study will run various simulations under the Tunisia scenario. Both the cargo and vehicle asset pools will be adjusted to show how these changes of inputs affect ELIST outputs. Additional capabilities of ELIST and how they relate to AFRICOM's ALN are also discussed.

Assumptions/Limitations

Several key assumptions are made when running the two models. When running AST, it is assumed that unlimited cargo aircraft are available to flow cargo into the airports. Thus, the limitation is the airport itself, and not aircraft assets. There are no financial constraints placed on the simulation either, so costs to operate at the airport are not factored. No additional personnel or handling equipment are added to the airport, so the studies show what capabilities the airport has without additional assistance. The AST also focuses on cargo flow only and not passenger flow. Finally, the AST assumes commercial operations at the airport are not disturbed by the incoming military aircraft.

The ELIST portion also has several key assumptions. ELIST expects all cargo to arrive at the port of debarkation according to plan, and does not allow for planned deviations. In this study, only road and railway networks and assets are used. No intra-theater airlift, helicopters, waterways, or pipelines are used. The original plan that is run under the Tunisia scenario has passengers, but all manipulations beyond this plan eliminate passengers and focuses solely on cargo movement. Other smaller scale assumptions are listed in both the methodology and results portions of this study.

Limitations on the study include the age of the site surveys used to conduct the AST simulations. These surveys were conducted in 2005, and multiple changes could have occurred at these airfields in the last four years. Limitations on the ELIST portion of the study include its classified nature, inherent complexity, and limited capability to manipulate cargo movement plans. This study only looks at airport throughput and intra-theater movement, and does not consider inter-theater cargo movements.

Implications

The implication of this study is to show the potential uses of mobility models to AFRICOM logistics planners. By using AST and ELIST to simulate deployments, AFRICOM is reducing the risk in their plans, and allows AFRICOM to forecast potential constraints in future operations. It also gives them an idea of how many and what types of vehicle assets are required to effectively operate in multiple locations. Finally, AFRICOM can use the models to test its ALN concept without wasting vital resources. Limitations of the models and their uses are also discussed.

This graduate research paper discusses Africa's strategic importance as well as the current ground transportation network in Africa. AFRICOM's creation and mission are also introduced, as well as the use of CSLs and the ALN theory. The methodology section describes AST and ELIST and details the assumptions used for both models. The results section gives an overview of the outputs of AST for three African airfields (Dakar, Entebbe, and Mombasa), as well as ELIST outputs for Tunisia. The paper then makes recommendations on how to further use AST and ELIST to model the African theater. Limitations of the study and future research are also discussed.

II. Literature Review

This chapter begins with a brief overview of the strategic importance of Africa and then progresses into Africa's current infrastructure issues. This sets the stage for why the United States is interested in moving cargo in Africa and more importantly why it is problematic to do so. The current transportation infrastructure is fraught with compatibility problems, poor maintenance, and suffers from a general lack of resources, and these issues are unlikely to change in the near or foreseeable future. This chapter moves on to discuss the creation of the United States Military's sixth geographic combatant command—Africa Command (AFRICOM). AFRICOM was created in October of 2008 for purposes of fostering human development goals as well as carrying out traditional military missions. AFRICOM has an extremely limited footprint in Africa, and relies on using cooperative security locations or CSLs to aid the movement of goods through theater. Two CSLs are considered in this paper, Dakar and Entebbe, as well as a third non-CSL, Mombasa. The chapter shifts gears from this point to discuss the adaptive logistics network (ALN) philosophy. As opposed to the traditional military supply chain, AFRICOM wants to use in-country logistics providers to move cargo throughout the continent. The ALN is a broad term that describes this type of supply chain.

The Strategic Importance of Africa

Africa was of extreme importance to America long before America was even a country, although in an auspicious manner. As Europe built empires in the New World in the 15th Century, it needed a labor force, and thus the slave trade began, and continuously increased in the Americas. At its height from 1700-1800, over 6 million slaves were imported to North America (Lovejoy, 2000). However, with the abolishment of slavery in the United States, trade (and strategic importance) between the African continent and the United States was drastically reduced for the next 100 years. Kansteiner and Morrison (2004) in a Center for Strategic and International Studies Report initiated by Congress referred to America's view on Africa during this timeframe as a "humanitarian afterthought."

However, in the 1990s Africa began to reemerge in strategic importance to the United States. Kansteiner and Morrison (2004) identify five factors that have shaped increased interest in Africa in the past decade: oil, global trade, armed conflicts, terrorism, and HIV/Aids.

United States energy stakes in Africa climbed steadily through the 1990s as West and Central Africa emerged as oil producers. In 2006, Africa surpassed the Middle East as the United States' largest supplier of crude oil, and Nigeria, Africa's top oil supplier, is the fifth largest supplier to the United States (Authers, 2007). Other countries that could benefit from an increase in African oil production include Angola, Algeria, Equatorial Guinea, Chad, Sao Tome, and Principe (Kansteiner and Morrison, 2004). Experts estimate that by 2015, Africa could supply as much as 25% of all U.S. oil imports, which would be in line with President Bush's goal of replacing 75% of oil imports from the Middle East as stated in his 2006 State of the Union Address (Ploch, 2008).

Related to oil would be Africa's emergence in global trade. Trade between Africa and the United States has tripled since 1990, with the bulk of the goods being natural and energy resources (Ploch, 2008). An initiative to support trade growth, the African Growth and Opportunity Act (AGOA), was started by the Clinton Administration in

2000. It has continued in the Bush Administration, most recently updated in 2006 (Ploch, 2008). AGOA imports in 2007 totaled $51.1 billion which was six times more than the initial year of 2001 (USTR, 2008). The majority of this trade was petroleum products, but $3.4 billion was non-oil which is double the amount of non-oil imports in 2001. As trade increases, the United States also has a goal to promote capital market development in Africa, and in 2007, was the leading nation in foreign direct investment in Africa totaling $13.8 billion (USTR, 2008).

Political conflict and instability in Africa has undermined economic, social, and political development and caused immense human suffering. In their Report to Congress, Kansteiner and Morrison (2004) state that one of the most critical threats to the United States is African conflicts citing that on no other continent is the question of order so problematic. In 2004, there were serious crises in 9 countries and multiple other countries where potential for conflicts loom (Kansteiner and Morrison, 2004). Ploch (2008) points out that, while the total number of conflicts has declined in the past few years, the continent is home to the majority of United Nations peace operations with seven currently underway. The civil war in Sudan is the longest running conflict on the continent and accounts for one of the most well known humanitarian disasters in the Darfur region. While many countries including the United States have considered this conflict as genocide and called for immediate action, the conflict continues as the United Nations UNAMID works to promote peace and protect civilians there. Conflict in Somalia led the United States to insert troops there intermittently from 1992 to 1995, and while no American troops were involved, conflict reignited there briefly in late 2006 and early 2007.

Some African nations have provided a great deal of aid in the prevention of conflict. Ethiopia, Ghana, Nigeria, and South Africa all rank amongst the top 10 troop contributing nations for U.N. peacekeeping operations (Ploch, 2008). To further assist African peacekeeping, the G8 introduced the Global Peace Operations Initiative in 2004. This multilateral program has a goal of training over 75,000 troops, the majority of them African, by 2010 to further promote stability in Africa (Ploch, 2008).

The Bush Administration has identified anti-terrorism as a top national security priority (Ploch, 2008). The 1998 terrorist attacks on the U.S. embassies in Nairobi, Kenya and Dar es Salaam, Tanzania and more recent attacks in Algeria, Mauritania, Egypt, and Morocco highlight the presence of terrorism on the continent. One DOD official stated that "Africa has been, is now, and will be into the foreseeable future, ripe for terrorists and acts of terrorism" (Ploch, 2008). Furthermore, the National Security Strategy of the United States issued by the President in 2002 stated that Africa has become vitally significant in the quest to combat transnational terror networks and their state sponsors (Kansteiner and Morrison, 2004). One primary concern when considering Africa is the vast amount of "ungoverned spaces" defined as "physical or non-physical areas where there is an absence of state capacity or political will to exercise control." (Ploch, 2008). Powell (2004) refers to such an area as "the terrorism triangle" encompassing parts of Morocco, Mauritania, Algeria, and Mali. This 3.3 million square mile area could be a new front in America's global war on terror, and could soon succeed Afghanistan as the world's number 1 haven for fanatic Islamic militants (Powell, 2001). The Pan Sahel Initiative launched by the Bush Administration provides $7.75 million for US military training for the armed forces of Mali, Niger, Mauritania, and Chad, and the

Pentagon also wants $125 million to train anti-terrorist forces in Morocco, Tunisia, and Algeria (Powell, 2004).

Additionally, African conflicts have led to a collapse of security and administration in many areas. This collapse links the African conflicts with terrorism. Al Qaeda capitalized on conflicts in Sierra Leone and Liberia to set up diamond trading to fund its operations (Ploch, 2008). While no substantial link has yet been proven, there is a great deal of speculation that piracy acts off the failed state of Somalia are also funding terrorism and have links to Al Qaeda (TimesOnline, 2008) (Chalk, in a 2008 RAND Report, indicates that piracy and terrorism have separate goals and specifies that no link between the two have yet been proven).

Finally, former Secretary of State Colin Powell referred to HIV/AIDS as "the greatest threat of mankind today" in a 2004 speech in Haiti (Ploch, 2008). According to the United Nations, there were over 22 million HIV positive Africans in 2007, representing 67% of infected persons worldwide (UNAIDS, 2008). The same UNAIDS Report showed that most southern African nations all have infection rates of 15-28%, which is the highest rate in the world (UNAIDS, 2008). Taking this into account, the Bush Administration created the U.S President's Emergency Plan for AIDS Relief (PEPFAR) in 2003. This initiative committed up to $48 billion to HIV/AIDS programs (Ploch, 2008). 12 of 15 PEPFAR focus countries are in Africa, and this high rate is attributed to poverty, women's lack of empowerment, and high rates of male worker migration (Cook, 2006). In 2008, President Bush signed law that expands PEPFAR through 2013 (PEPFAR Website, 2008). The United States along with other G8 nations in 2007 have set future goals of preventing 24 million new infections and treating 5 million HIV-infected individuals, as well as cut malaria related deaths by 50% in 30 countries (PEPFAR Website, 2008).

Additional insight into the strategic importance of Africa was provided by Lake and others (2006) in their *Council on Foreign Relations Independent Task Force Report*. This report was well summed up in Nichols (2008) graduate research paper *Analysis of AFRICOM Theater Airlift Distribution Network.* The task force recommends that the United States develops a more comprehensive U.S Strategic policy for Africa based on Africa's oil and energy imports, terrorism issues, HIV/AIDS pandemic, and conflicts such as Darfur and other humanitarian disasters such as the Rwandan genocide. It also points out that African nations now secure nearly a third of the votes in the World Trade Organization. While it cites different sources, it generally mimics Karnsteiner and Morrison's 2004 Center for Strategic and International Studies report and Ploch's 2008 CRS Report for Congress that spells out the previously defined five factors that shaped African's Strategic importance.

Lake and others (2006) also discuss China's new roll in Africa, which is also of U.S. interest. China is continually acquiring control of Africa's natural resource assets by outbidding Western contractors and providing soft loans and other incentives to bolster its competitive advantage (Lake and others, 2006). According to Bosshard (2007), trade between Africa and China, primarily consisting of oil, timber, and minerals, has increased tenfold from 1999 to 2006 reaching $56 billion in 2006. China imports 28 percent of its oil from Africa, mostly from Angola, Sudan, and Congo (China is now the world's second largest oil importer) (Lake and others, 2006). China does not report on its foreign development assistance, but it is estimated to have been $5.7 billion in Africa in 2006

(Bosshard, 2007). Additionally, an estimated 700-800 Chinese companies are operating in Africa (Bosshard, 2007). China has not been afraid to use its influence in Africa, continuously blocking United Nations Security Council humanitarian and peace efforts in the Darfur region of Sudan. Sudan, as previously mentioned, is one of China's primary African trade partners, and their efforts to support the Sudanese government has shown other African countries that China can be a strong ally (Lake and others, 2006). As the influence of China in the affairs of Africa continues to grow, the United States will be forced to match some of China's efforts or be forced off the continent and lose access to its resources.

African Infrastructure

The term infrastructure itself can refer to multiple different aspects. Dictionary.Com defines infrastructure as "The fundamental facilities and systems serving a country, city, or area, as transportation and communication systems, power plants and schools." Other definitions include sewer and water systems, irrigation systems and even law and order mechanisms. Jerome (2004) broadly defines infrastructure as "all basic inputs and requirements for the proper functioning of the economy." Infrastructure is often also broken down into two categories: social and economic infrastructure. Social infrastructure refers to education, law, and health services which facilitate the supply of skilled and healthy personnel to manage and operate other resources (Jerome, 2004). Economic infrastructure provides society with the services necessary to conduct daily life and engage in productive activities (Jerome, 2004). Power, transportation, telecommunications, water, sanitation, and safe water disposal all fall under economic infrastructure. While Africa trails the rest of the world in the entire domain of economic infrastructure (Jerome, 2004), this paper will focus on the transportation infrastructure of Africa, and even more specifically, roads, railways, and airports. The road, railway (and port) networks throughout Africa were mainly built during the colonial era and are not well connected, and this poor infrastructure has blocked the quick movement of goods and pushed up transport costs (Costa, 2008).

Jerome's 2004 African Development Bank Research Paper, *Infrastructure in Africa: The Record* covers the state of all types of economic infrastructure. In terms of the entire transportation network, Jerome (2004) considers it important for both the promotion of intra- and extra-African trade. However, Jerome also summarizes its condition as inadequate and ineffective, and in general in need of repair and maintenance requiring a high level of funding. A summary of Jerome's comments on road, rail, airports and landlocked countries follows with additional references where applicable.

Roads. According to Cheick Sidi Diarra (2008), the U.N. Special Advisor on Africa, 90% of all inter-urban transport in Africa is achieved via road transport on Africa's 1.2 million mile road network. However, less than a third of the roads are paved, and transport costs account for as much as 77% of the value for African exports (Diarra, 2008). Jerome (2004) cites that the fragmentary nature of the railway networks as well as the limitations in scope of inland waterways account for the high usage of the road network. Jerome (2004) goes on to break down the paved roads by region, with 57.4% of North Africa's roads, 10.2 % of Central Africa's roads, and 25 % of South Africa's roads paved. Road density per square kilometer is less than that of both Asia and Latin America. Throughout Africa, road building has been considered a higher priority than road maintenance, and thus, over half of the paved roads are in poor condition (Jerome, 2004). Additionally, over 80% of the unpaved roads in Africa would be considered just fair, and 85% of the rural feeder roads are in poor condition and cannot be used during the wet season (Jerome, 2004 and Mutume, 2002).

During the 1960s, African leaders realized that transportation would be vital to Africa's economic future (Mutume, 2002). Plans were drawn up to create the trans-Africa Highway system linking Cairo to Dakar, Tripoli to Windhoek, and Lagos to Mombasa, providing access to the sea to 15 landlocked countries (Mutume, 2002). However, this network does not yet exist, and international coordination has been ineffective (Jerome, 2004). Instead, according to Flanakin (2006), a trip that should take three days from Bangua, Central African Republic to Douala, Cameroon takes 11 days and costs $580 to pass local barricades.

The high cost of building and maintaining roads is certainly the largest hurdle to African road expansion. Crude estimates show that Africa spends only one third of the amount that would be needed to provide just adequate infrastructure (Mutume, 2002). Mutume (2002) gives an example of the costs of building roads versus GDP using Ethiopia. To bring 90% of Ethiopia's population within 12 miles of an all weather road would cost $4 billion, which is 75% of the countries annual GDP. However, Mutume (2002) also cites World Bank studies that show a 10% drop in transportation costs in Africa could result in a 25% increase in trade. While Mutume (2002) feels the bulk of the costs to upgrade roads must fall on the countries' governments themselves, outside aid and investments to improve roads will be necessary. One plan proposed by World Bank's Development Research Group proposes a 62,000 mile road network that would connect every sub-Saharan capital on the mainland and an additional 41 cities with populations over 500,000. The plan's cost: an estimated $47 billion over 15 years, with an expected economic yield of $250 billion over 15 years (Flanakin, 2006). Weiss (2004) also cited two studies that estimated the return rate for developing countries on infrastructure improvements to be between 63% and 95%.

While the state of African roads has been shown to be abysmal, an additional problem is that of road travel safety. Bad roads, old vehicles, and lack of regulations and enforcement lead to unsafe road networks. In the world's most highly motorized countries, the average death rate per 10,000 motor vehicles was 2.3. In a sample of African countries, the death rate per 10,000 vehicles was 339, over 147 times higher (Mutume, 2002).

Demand for the roads that do exist is also continually increasing. Simuyemba (2004) notes that railways in east and southern Africa suffer from such poor performance that bulk materials such as copper, steel, coal, timber, and grain are increasingly being transported long distances via road as opposed to rail, leading to considerable damage to the road network. As agriculture and industry expand and national and sub-regional economies develop, existing road networks will require "tremendous extensions and improvements in quality" (Jerome, 2004). Again, this will require heavy capital investment, and Africa as a collective has yet to show that it is willing or able to make this investment.

Figure 1: African Road Network

Railways. African railways are fragmented, and not as much a linking system as they are lines connecting the interior directly to ports. Only in Eastern and Southern Africa is the network connected. All were built during the colonial era (end of 19th century or beginning of 20th century), and as such had a focus on external trade purposes versus creating a network to move goods within Africa itself (Jerome 2004). They were also built with different technical characteristics, gauges, couplings, brake systems, and buffers. The 1.067m gauge predominates, especially in sub-Saharan Africa while the 1.435m gauge accounts for 76.1 percent of the lines in the North African Region (Jerome, 2004). Africa has an estimated 45,260 miles of track, 30% of which lies in the country of South Africa alone (Jerome, 2004). Jerome (2004) also notes that 12 countries (Burundi, Central African Republic, Chad, Cape Verde, Comoros, Djibouti, Mauritius, Seychelles, Somalia, the Gambia, Guinea Bissau, and Libya) have no railway system at all. Most lines are not suitable for fast or heavy traffic, and are lightly used (other than the North African region). Most are also in deterioration due to lack of proper maintenance.

Much like the United States, trucking is a more popular means of moving goods. Railways are under increased competition in the transport market, and most have lost traffic to roads over the last two decades (Simuyemba, 2004). Freight rates by rail are on average twice as high as those in Asia, and one and a half times those in Latin America, but the railways run at a deficit (Jerome, 2008). The major cost associated with the railroad industry is the operation, maintenance, and ownership of tracks themselves (Coyle and others, 2006). Initial cost of track is a large capital investment, and annual maintenance is a substantial drain on earnings. In the US, capital expenditures in 2001

Figure 2: African Railway Network

amounted to $5.4 billion (Coyle and others, 2006). Despite these high costs, there are plans for 15 new lines in East Africa that were released in April, 2008 connecting Ethiopia, Sudan, Kenya, Uganda, Tanzania, Burundi, Rwanda, and the Democratic Republic of Congo (Sambu, 2008).

Airports. Jerome (2004) cites that all African countries have at least one international airport as well as several smaller ones (Egypt (17) and Nigeria (15) have the most). All of the airports in Africa are characterized by deteriorating runways, obsolete traffic control equipment, and lack of modern equipment and infrastructure. Customs, air cargo, catering, baggage handling, and connecting surface transportation are all lacking compared to market demands, and maintenance capabilities are not on par with most facilities at large airports throughout the world. Operational and safety shortcomings at Nigeria's airports have given them the reputation as being the worst in the world.

Landlocked Countries. Jerome (2004) briefly comments on Africa's Landlocked countries pointing out that they are amongst the poorest nations in the world. Relative to coastal African countries, all aspects of infrastructure lag far behind inhibiting economic growth. Related to transportation, all of these countries rely on neighboring countries for reliable delivery of goods. Intermodal complications created by non-coordinated rail schedules, differing rail systems, and customs delays by road transport compound problems for landlocked countries. For a Ugandan business to receive ordered goods from Europe, it can take as long as three and a half months from shipment date in Europe to arrival in Kampala.

AFRICOM

United States military operations in Africa date back to 1801 during the first Barbary War in Tripoli, Libya when a small group of marines landed to free the crew of an American ship being held there (Fact Sheet, 2009). From the 1800s up until World War II, military actions in Africa continued to be on a similarly small scale. This changed in late 1942 when the United States conducted Operation Torch, an amphibious landing in Morocco and Algeria to join in the North African Campaign. Eventually, the US used northern Africa as a launching and staging point for operations in southern Europe (Fact Sheet, 2009).

Following World War II, the United States kept a presence in Africa at Wheelus Air Base near Tripoli. From the 1940s until 1971, an average of 4,000 American personnel manned the base until the U.S. withdrew at the request of the Libyan government (Ploch, 2008). Up until 1952, Africa was not included in the United States military command structure despite the existence of a base on the continent. However, in 1952, several North African countries, including Libya, were added to European Command based on their historical association with Europe (Ploch, 2008). In 1960, Sub-Saharan Africa was added to Atlantic Command due to Cold War concerns, and then transferred to Strike command in 1962. This responsibility was dissolved in 1971, leaving Sub-Saharan Africa out of the military command structure again until 1983, when all of Africa was split between European Command (EUCOM), Pacific Command (PACOM), and Central Command (CENTCOM) (Ploch, 2008).

During the 1980s, there were several military engagements with Libya. This culminated in April 1986 with a U.S. airstrike against multiple military targets in Libya after territory disputes and a link was found between the Qadhafi regime and terrorism (Ploch, 2008). These strikes were the first major American effort to attack the terrorism support network in Africa. In the early 1990s, the focus shifted to Somalia and two humanitarian operations there (Operation Restore Hope and United Nations Operation in Somalia). These operations brought unprecedented American presence in Africa as over 25,000 soldiers were deployed to Somalia (Ploch, 2008). The Somalia Operations ended in 1994, but 3,600 soldiers were deployed that same year to Central Africa to provide humanitarian assistance in Rwanda (Ploch, 2008). In 1995, the Department of Defense summed up its view on Sub-Saharan Africa by stating "ultimately we see very little traditional strategic interest in Africa" (Ploch, 2008). However, this short sighted vision started to change in 1998 with the al Qaeda bombings of the U.S. embassies in Kenya and Tanzania.

Since 2000, there have been a continuously building number of U.S. military operations in Africa. Ploch (2008) notes that between 2000 and 2006 there were at least 15 major instances of the use of U.S. Armed Forces in Africa, most dealing with either terrorism threats or instability on the Horn of Africa. The failed state of Somalia continues to create problems in the region. The only U.S. military base in Africa is Djibouti at Marine Camp Lemonier with over 1500 military personnel. It is an effort to add some stability to this region (Ploch, 2008). Combined Joint Task Force Horn of Africa covers the land and air areas of Kenya, Somalia, Sudan, Seychelles, Ethiopia, Eritrea, Djibouti, and Yemen. It is tasked with detecting, disrupting, and ultimately defeating transnational terrorist groups in the region. Its forces operating out of Camp Lemonier train the regions security forces on counter terrorism, collect intelligence, serve as advisors to peace operations, conduct activities to maintain maritime access, and support humanitarian assistance efforts (Ploch, 2008).

The growth in the strategic importance of Africa already covered in this paper has gone hand in hand with an increasing amount of military importance in Africa. In 2006, the commander of EUCOM, General James Jones, said his staff was spending more than half their time dealing with issues in Africa, up from almost none three years prior (Note that the Horn of Africa was covered by CENTCOM. Thus, the increased workload on EUCOM was not caused by Horn of Africa issues) (Ploch, 2008). While increasing strategic importance was one cause for creating a separate African Command, problems dealing with the “seams” of the three commands that have responsibility in Africa was another. As an example, U.S. forces working as peacekeepers in Sudan (a country under CENTCOM’s responsibility) have had most of their airlift and training provided by EUCOM (Ploch, 2008). Additionally, both EUCOM and CENTCOM are stretched thin. CENTCOM obviously by the wars in Iraq and Afghanistan, and EUCOM by responsibility in 92 separate countries. General Bantz Craddock, EUCOM commander, stated before congress that

> The increasing strategic significance of Africa will continue to pose the greatest security challenge in the EUCOM AOR. The large ungoverned area in Africa, HIV/AIDS epidemic, corruption, weak governance, and poverty that exist throughout the continent are challenges that are key factors in the security stability issues that affect every country in Africa (Ploch, 2008).

Recognizing the growth in Africa’s strategic importance, problems with COCOM boundaries in Africa, and that the main two players on the continent, EUCOM and CENTCOM, were stretched thin, President George W Bush announced on February 6th, 2007 that a new COCOM would be created (Ploch, 2008). The mission statement of

AFRICOM approved in 2008 is "in concert with other U.S. government agencies and international partners, conduct sustained security engagement through military-to-military programs, military-sponsored activities, and other military operations as directed to promote a stable and secure African environment in support of U.S. foreign policy." (AFRICOM website, 2009). AFRICOM is most like Southern Command (SOUTHCOM) in that their mission is to supervise an array of operations that relate to U.S. strategic interests but are not combat-related (Ploch, 2008). One DOD official suggested that AFRICOM' would be a success "if it keeps American troops out of Africa for the next 50 years" (Ploch, 2008). Another aspect of AFRICOM that separates it from other commands is its interagency focus. AFRICOM is seeking greater interagency coordination with the State Department, the United States Agency for International Development (USAID), and many other governmental agencies (Ploch, 2008). It has reinforced this commitment by making many higher level positions within the command civilian posts, including the deputy commander position held by Ambassador Mary Carlin Yates. Ambassador Yates (formerly the Ambassador to Burundi and Ghana) is the first non-DOD civilian to be integrated into the command structure of a unified command.

AFRICOM will cover 53 different countries within its AOR. Africa, almost in its entirety including its island nations, is now under the single unified command (Egypt was kept under the CENTCOM AOR due to the similarities and proximity it had with other CENTCOM countries). The command's headquarters are in Stuttgart, Germany, although this may not be its final location. AFRICOM is under some Congressional pressure to be headquartered on the African continent. However, there has been negative reaction domestically and internationally to placing the headquarters in Africa as many feel this would be the first step in a U.S. military agenda to establish a larger footprint on Africa (Ploch, 2008). These fears have caused countries such as South Africa, Kenya, and Algeria to express reluctance in hosting the command. Other countries, on the other hand, have expressed interest, most notably Liberia (Ploch, 2008). The reluctance by many to host the command, along with the fact that Africa's living standards and stability are so far below that preferred by the DOD will probably continue to keep the command outside of Africa for the foreseeable future (EUCOM's headquarters in Stuttgart is the only other COCOM headquarters stationed outside the United States which leads some to believe AFRICOM will stay in place to be alongside EUCOM or move to within the United States). Like CENTCOM and SOUTHCOM, AFRICOM will not have permanent assigned personnel outside of the headquarters staff. Instead, military personnel will be deployed for operations and exercises as necessary. Resources will be handled in much the same manner, although the Air Force component of AFRICOM, 17th Air Force, does have two C-130 transport aircraft assigned to it for use on the continent (Venne, 2009).

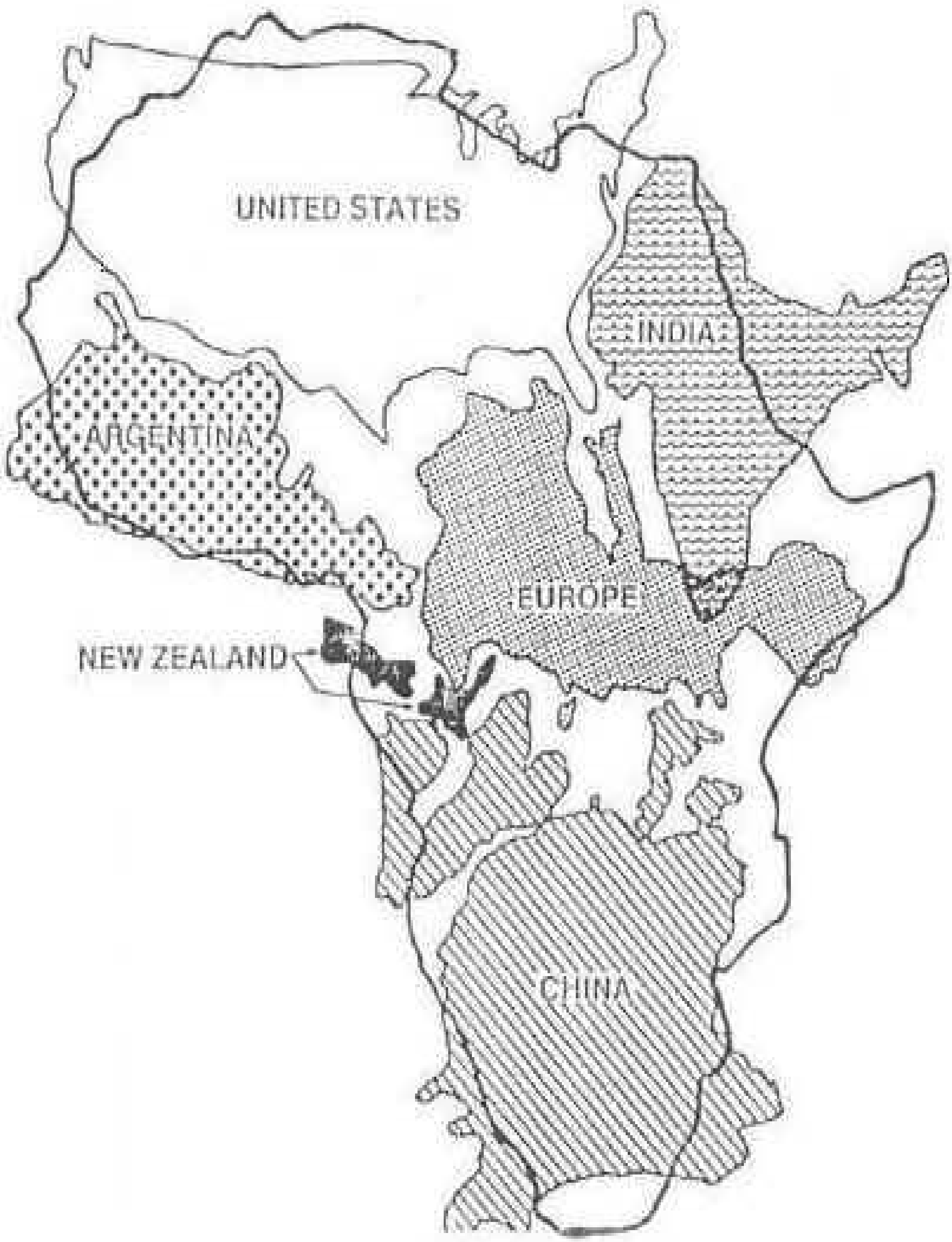
AFRICOM was activated on 1 October 2008 and is commanded by Army General Kip Ward. It becomes the sixth regional unified command and tenth unified command. Its first large scale operation concluded 16 January 2009 which was in support of humanitarian operations in Darfur, Sudan. U.S. Air Force C-17 transport planes staged out of Camp Lemonier lifted nine 20,000 lb. trucks from Rwanda to Sudan to facilitate ease of movement for the NATO peacekeeping forces stationed in Darfur (Rising, 2009). This first successful mission demonstrates both that AFRICOM is fully functional, and also that its intentions of being non-combative in nature are more than just intentions but a reality.

Cooperative Security Locations

Africa is immense in sheer size at 11,205,146 square miles. The Continental United States, China, India, Europe, Argentina, and New Zealand combined have less square mileage (How Big is Africa, 2009). As previously mentioned, the U.S. military covers the continent with one Marine Base, Camp Lemonier in Djibouti. However, the United States does have other bare-bones facilities in Africa called Cooperative security locations or CSLs. Joint Publication 1-02 Department of Defense Dictionary of Military and Associated terms (2001) defines a CSL as "a facility located outside the United States with little or no permanent U.S. presence, maintained with periodic Service, contractor, or host nation support." The DOD also refers to CSLs as "lily pads" (Ploch, 2008). CSL's provide contingency access, logistical support, and rotational use by operating forces and are a focal point for security cooperation activities." (It is important to note that the word Service in the definition is referring to U.S. military branches of service such as Army, Navy, Air Force or Marines. Cornella and others (2005) state that even when used, it is up to the Service to support the CSL and not the COCOM. These facilities may contain prepositioned equipment, are rapidly scalable, and located for tactical use. They are forward and expeditionary in nature, and can be expandable to become a forward operating site when conditions require (Cornella and others, 2005).

Cornella and others (2005) in a report to Congress comment specifically on the African CSLs saying:

Figure 3: Size of Africa Compared to Countries of the World



> The series of CSLs provide, in time of need, a foothold for conducting the full range of military options, forced entry, humanitarian relief, NEO, peacemaking, peace keeping, and other stabilization operations. In many cases, the CSLs provide deployment support for forces or transport deployment and throughput. They may contain pre-positioned equipment and/or provide for logistical arrangements. The cooperative security locations serve both security cooperation activities and contingency access.

Cornella and others (2005) go on to assess that CSLs not only provide operational flexibility, but also preserve a presence abroad and help strengthen our relationships with host countries. Because little or no U.S. troop presence is needed, there is less worry about the standards of living at these locations, and also a lower associated monetary cost (Cornella and others, 2005). In their Report to Congress, Cornella and others (2005) advocate more African CSL locations, but do not go into establishing where these should be located, instead arguing for interagency investigation of potential new locations. They also caution placement of CSLs citing that they could potentially cause agitation amongst Muslim populations or inflame terrorist groups.

Cornella and others (2005) also define necessary aspects that are required of a location to be a CSL. To be effective, a CSL must maintain a constant state of readiness despite the fact that it could go years with little or no permanent presence. If it is at an airport, then the airport must provide adequate runway and ramp space. If it is a seaport, it must have adequate roll on, roll off capacity. The CSL must also have the adequate infrastructure to support Reception, Staging, Onward Movement, and Integration (RSO&I). Finally, it would be desirable to have training range access, so that U.S. troops could rotate through the CSL to train with host-nation forces.

Currently, Africa hosts CSL locations in Algeria, Botswana, Gabon, Ghana, Kenya, Mali, Namibia, Sao Tome and Principe, Senegal, Sierra Leone, Tunisia, Uganda and Zambia (Ploch, 2008 and Cornella and others, 2005). Cornella and others (2005) note that while these CSLs are well established, little has been done to counter the expansion in Africa of potentially hostile competitors there. Again they state that more CSL's are probably required in Africa to create a broader network of U.S. coverage on the continent.

Adaptive Logistics Network

The immense size of the African continent and span of AFRICOM's responsibility along with Africa's feeble transportation infrastructure creates an impressive and complex problem for AFRICOM's Deployment and Distribution Operations Center (DDOC). Already faced with what is often called "the tyranny of distance," the DDOC also only has two C-130s at its disposal to move personnel and supplies into Africa, and once there, almost no ground support to move anything forward. General William E. Ward, commander of AFRICOM, laid out six guiding principles for his AFRICOM staff, one of which was to "encourage innovative thinking, challenge assumptions, and create new paradigms" (Fact Sheet, 2009). This is clearly what the DDOC has been charged with doing in order to operate in Africa; think outside the box in order to provide AFRICOM the robust logistics support that is required to perform its mission. The DDOC also must adhere to JP 4-0, *Joint Logistics*, in achieving logistics economy by "using the fewest resources within acceptable levels of risk" (CJCS, 2008).

To overcome the daunting logistics task, the DDOC is going beyond the traditional military logistics network concept of using primarily its own assets to move assets throughout theater. Instead, it is trying to create what it calls an Adaptive Logistics Network or ALN. The ALN concept "capitalizes on the entire logistics capability available in Africa. This includes access to and use of the logistics capabilities of DOD, US government agencies, partner nations, allies and industry working in Africa" (D'Angelo, 2008). This is a concept that Rear Admiral Mike Lyden (now the commander of Naval Supply Systems Command) briefed at the National Defense Industrial Association's Annual National Logistics Conference in March 2008 as Big "J" logistics integration (Lyden, 2008). Whereas the term "joint" in a military context signifies more than one branch of military service, Admiral Lyden (2008) refers to Big "J" as going beyond military services to include State Department, NATO, UN, European Union, African Union, private industry, and non-governmental organizations (NGOs). Admiral Lyden (2008) specifically points out that NGOs have a wealth of logistical experience and have established working relations with all types of supply chains worldwide, both large and small, to rapidly move goods to austere locations on shoestring budgets while using a smaller footprint than typical military solutions. The bottom line is to produce a logistics network that enhances synergy and reduces both redundancies and costs while eliminating risks associated with a single point of failure (Lyden, 2008). Admiral Lyden's views are now expressed in doctrine in the new JP 4-0 *Joint Logistics* as it now dictates "coordination and sharing of resources from multinational partners, intergovernmental organizations, and non-governmental organizations" (CJCS, 2008). JP-04 emphasizes this statement saying "the Services, by themselves, seldom have sufficient capability to independently support a joint force" (CJCS, 2008).

Another call for a change from the traditional military logistics structure came from Castano-Pardo and others (2006) in an IBM Institute for Business Value study. They argue that military logistics must keep pace with ever faster operational execution by becoming increasingly collaborative and increasingly adaptive. Castano-Pardo and others (2006) noted that while "military missions simply cannot be effective without adequate logistical support, lagging logistics capabilities hamstring operational execution." Like Lyden, they call for the military to look outside its own organizational collaboration and look to external collaboration to expedite logistical needs. Castano-Pardo (2006) refer to their adaptive logistics model as "sense and respond" logistics, or the "ability to sense events or situational changes in realtime and respond rapidly and effectively."

The AFRICOM ALN concept includes both the sense and respond concept as well as the multi-organizational framework. Its other underlying feature is the ability to work across the full spectrum of logistics needs from small packages to multiple pallets of cargo or even troop movement (Schantz, 2008). The small package solution could be as simple as outsourcing the movement to FEDEX, who conducts operations throughout Africa, and already has a military contract (Kadivnik, 2008). However, pallet sized cargo or passengers will require use of in-country resources. The ALN needs to have the ability to morph to the needs of AFRICOM's demands, and be able to do it rapidly. In summation, the ALN requires "the seamless connecting of supply, planning, contracting, and distribution operations and rapid decision making capability driven by real time visibility across the logistics process" (D'Angelo, 2008).

While the concept of an ALN is a bold step for the US Military, making it a reality will be much more difficult. As D'Angelo (2008) points out, this network requires a "robust knowledge base of available logistics capabilities to include distribution capacity, supply items, locations of resources, cost to acquire and access these resources."

Once this data is ascertained, the network requires a second step of having real-time visibility on all of these capabilities to know what is available when a need arises. Finally, the network must be able to rapidly obtain the resources and services when needed. Making this task increasingly difficult will be developing trust amongst the multiple organizations to open up their stovepiped logistical networks to AFRICOM. Once this trust barrier is removed, AFRICOM may still have issues with in-place DOD contracting procedures. The contracting procedures are unreceptive to the rapid nature that the DDOC wants to be able to use in the ALN's structure. D'Angelo states that the ability to employ the ALN concept is in place today, but it will require changes to current DOD systems and processes (D'Angelo, 2008).

Another focus of the ALN is on the use of in place resources. This is important to AFRICOM on multiple levels. First, it will bring business to the African companies that provide the services. Road freight is the dominant mode of transport for intra-African trade, and the majority of the providers are private sector small owner/operator fleets (Simuyemba, 2004). Second, it will establish relationships with these businesses that will allow the network to grow as the reputation of good business with AFRICOM spreads. Once a positive business encounter occurs, that provider will be more willing to work with AFRICOM in the future. Finally, it will support the AFRICOM mission in that it will create a "more stabile African environment" and directly pump aid into the growing African economy. The hopes are that as more activity in Africa builds, the contracts given to African businesses will help to modernize African countries. In a similar context, a high ranking CENTCOM Logistics officer speaking in terms of the countries north of Afghanistan said “the number one way to engage these countries is through logistics.” This certainly pertains to the entire continent of Africa.

D’Angelo (2008) also establishes a three phase plan to execute AFRICOM’s ALN. Phase I consists of integrating and synchronizing the logistics capabilities of the multiple organizations in an effort to reduce duplication between agencies. Phase II will establish the collaboration to reduce seams between participating organizations and establish the exchange of near real-time information between participants and customers. Finally, Phase III will leverage the knowledge gained in Phase I and II to manage variability in the network and successfully incorporate the ALN into AFRICOM’s daily operations. D’Angelo (2008) estimates this process will take 14-18 months, but will also allow benefits in the interim by allowing a better understanding of how the multiple logistics networks in Africa are working in their current state and by supporting greater collaboration amongst them. Additionally, D’Angelo (2008) states that the limited established military footprint already in Africa is vital to the development of AFRICOM’s ALN. D’Angelo (2008) specifically points out the essential nature of the African CSLs; as they allow access and provide essential infrastructure requirements.

Literature Review Summary

The emerging strategic importance of Africa led to the creation of AFRICOM. The limited assets available to AFRICOM, combined with Africa’s poor infrastructure, force AFRICOM’s logistics planners to think outside the box. Use of the ALN and CSLs provides a framework for cargo movement, but planners must be able to estimate cargo movement times as well as throughput capacities. The remainder of this research focuses on ways mobility models can aid planners in measuring cargo throughput and travel time.

The following methodology section presents the capabilities of the AST and ELIST mobility models and the data requirements for each model. It discusses data sources and formats used by both models. Key assumptions that each model makes are also introduced.

III. Methodology

It would be impossible to accurately predict how many aircraft could be pushed through an airport in a given time period or how long it would take for cargo from those aircraft to move to its destination without actually measuring it over a period of time. Even then, many random variables exist that could change the throughput on a daily basis. However, U.S. Transportation Command (TRANSCOM) and the U.S. Air Force's Air Mobility Command (AMC) have to have an idea how rapidly aircraft can flow through an airport, and how long it will take to get cargo to its desired location in order to plan exercises and operations. It is also infeasible both in time and resources to actually measure this capacity at all locations in the world. To come up with reasonable estimates, TRANSCOM and AMC use computer modeling and simulation. Computer modeling is described by Ragsdale (2007) as "a set of mathematical relationships and logical assumptions implemented in a computer as a representation of some real world decision problem or phenomenon." Collectively, there are multiple models that are used to cover strategic lift, or movement from theater to theater; tactical lift, or movement within a theater, as well as throughput analysis of both seaports and airports. Collectively, several of these models are under the Analysis of Mobility Platform (AMP) federation. Those models within the federation are able to share common inputs and outputs so as to model cargo throughput from origin to destination. Two of these models within the AMP federation are the Aerial Port of Debarkation (APOD) model and the Enhanced Logistics Intra-theater Support Tool (ELIST). These two models are able to estimate airport throughput and in-theater movement.

APOD itself consists of three tool sets: the Airfield Simulation Tool, the Rapid Analysis Tool, and the Airfield Throughput Tool. Of these, the Airport Simulation Tool (AST) predicts the airfield capacity that an airfield can sustain over a defined amount of time or continuously. AST is capable of looking at multiple factors including flightline layout, parking area, cargo handling equipment and cargo capacity, fuel reception, storage and handling, and impact of aircraft maintenance problems and running a simulation to determine aircraft throughput at that airfield. Simulation itself is defined by Ragsdale (2007) as "a technique to measure and describe model performance when one or more of the independent variables are uncertain." AST runs a model of the airfield through multiple iterations to account for the variability, and then takes average values of these iterations to come up with an estimate. AST not only measures the capable throughput, but identifies the limiting factors as well. AST data for an airfield has to be populated prior to running a simulation on that scenario. Information to populate the AST database is typically gathered by conducting a site survey of the airfield to see what cargo downloading equipment, fuel, servicing vehicles, parking space, and cargo holding area is available.

ELIST, developed by Argonne National Laboratory, also uses simulation to determine the average time it takes for cargo and passengers to move from the arrival point in theater to its final destination in theater. The military refers to this type of movement as Reception, Staging, Onward-movement, and Integration (RSO&I), which was briefly introduced in the literature review. ELIST can duplicate AST's prediction of throughput at an airfield, but it is not as detailed as AST, which is therefore a better tool for conducting throughput analyses. However, ELIST is the model of choice for determining in theater cargo movement times (VanGroningen, 2009). ELIST predicts: if the theater infrastructure can support planned cargo movement; if the theater assets are enough to support given delivery dates; where system bottlenecks occur; and what effects of exogenous events are on the transportation infrastructure (VanGroningen, 2009).

ELIST's required input from the user is Time Phased Force Deployment Data commonly referred to by the military as TPFDD. A TPFDD defines when and where cargo and passengers need to be picked up and when and where they need to be delivered (McKinzie and Barnes, 2004). TPFDDs define when cargo is ready to load at the origin (RLD) as well as earliest arrival date in theater (EAD) and latest arrival date in theater (ALD). Together, the EAD and LAD give a window of when specific lines of cargo (called Unit Line Numbers or ULNs) need to be in place in theater. Violations of this window may negatively affect the safety of the mission, cargo, and passengers (McKenzie and Barnes 2004), and ultimately could lead to mission failure. Thus, U.S. TRANSCOM must find a way to deliver TPFDD cargo and passengers within this window, and likewise, planners have to build realistic TPFDDs. ELIST is a tool used to measure if the intra-theater TPFDD is realistic. All military deployments or plans have associated TPFDDs that organize the flow of cargo and passengers. A partial TPFDD can be seen in Table 1 (this example TPFDD portion does not give EAD, LAD or multiple other lines of data). (Note: ELIST actually uses Expanded Time Phase Deployment Data or ETPFDD. This is basically a TPFDD with additional data lines including additional movement location types, optional delays, an additional level of cargo detail, options for cargo to marry up at a given location, and options to relate Requirement Line Numbers (RLNs) to each other (Braun and VanGrogingen, 2003).

Since the military, in general, is more familiar with the generic term TPFDD, it will continue to be used in this paper. However, it will always refer to an ETPFDD).

Table 1: TPFDD Sample (from McKinzie and Barnes, 2004)

Line ID	Onload	Offload	Load	Required	Bulk	Oversize	Outsize	Passengers	Owner Type
UNIT1486	KBLV	RKPS	10	24	292	1,009	59	0	9
UNIT1487	KWRI	RKPS	10	24	116	349	35	0	23
UNIT1488	KTIK	RKPS	10	24	6	9	2	0	2
UNIT1489	KTCM	RKPK	10	24	0	0	15	0	5
UNIT1490	KTIK	RKPS	10	24	0	41	85	0	5
UNIT1491	PAEI	RKPS	11	24	0	110	5	19	2
UNIT1492	KSUU	RKPK	11	24	133	32	7	59	18
UNIT1493	KTIK	RKPS	11	24	29	764	9	0	18
UNIT1494	PHIK	RKPS	11	25	63	182	7	0	18
UNIT1495	KSUU	RKTY	11	25	634	562	880	0	4
UNIT1496	KDOV	RKJK	11	25	220	208	212	0	1
UNIT1497	KTIK	RKSO	11	25	0	190	83	402	1
UNIT1498	KHOP	RODN	11	25	47	44	12	44	1
UNIT1499	KLFI	PHIK	11	25	0	0	0	1,876	2
UNIT1500	KOFF	PHIK	11	25	0	0	0	814	2

ELIST must be populated with multiple sources of data for each theater it models. VanGroningen (2009) states four sets of data that must be populated in ELIST in order for it to be used within a particular theater: reference vehicle characteristics, rules for movement requirements, infrastructure capabilities, and assets available for movement. The vehicle characteristics include such items as speed and weight carrying capabilities. Rules include both the characteristics of what needs to be moved (typically included in the TPFDD) as well as rules for how to move the cargo passengers (preferences for modes can be set), and what priority each ULN is given. Infrastructure capabilities include what seaports, airports, roads, rail, waterways, and pipelines are in theater. The infrastructure is used to create the transportation network within a country. Contractors at the U.S. Army's Surface Deployment and Distribution Command (SDDC), which is under TRANSCOM, create the network in the form of Geographic Information System (GIS) databases. This is detailed information and includes the capacities that each highway, railway, waterway or airport/seaport is capable of throughputing. Finally, ELIST needs to know what assets are in place in the country to move cargo. ELIST also accounts for vehicles that are delivered as part of the TPFDD that can then be used to boost the host nation's assets. Assets can be assigned for direct delivery or linehaul on roads, and intra-theater airlift and helicopters can also be modeled.

Both AST and ELIST are models, and while both are validated, they have some limitations. First, models are tools to aid decision makers, but they cannot replace decision makers. Second, a model should not be pressed to do what it was not designed to do. Finally, and most importantly, a model is no better than the information that is used to create it (Ravindran, Phillips, and Solberg, 1987). This is especially important as both AST, and even more so, ELIST need to be populated by reliable and proven data in order to give a useful output. Often, gross errors can be caught by giving an unreasonable output, but in the end, inputs need to be checked in detail for accuracy.

This study examines the capabilities of three separate airports in Africa that were chosen for examination by AFRICOM by using AST. Two of these airfields, Dakar, Senegal and Entebbe, Uganda, are CSLs, while the third, Mombasa, Kenya, is not. The AST model is used to answer one of two questions posed by AFRICOM…how much cargo can be pushed through each of the three selected airports. The second question is, once the cargo is on the ground, how far can it be pushed into Africa. This question can eventually be answered using ELIST. However, at this time, ELIST is not populated for the three locations in Africa selected by AFRICOM for this study. U.S. TRANSCOM is working to fill this void and network the African continent in ELIST. Some areas of Africa are currently populated. However, the data that ELIST is populated with is classified in nature—which means that any output created within that area would also be classified. Because ELIST will be able to answer this question in time, this paper will address specifically how ELIST can be used by AFRICOM in the future by referring to an ELIST example simulation in Tunisia.

Data Sources

The data to populate the AST model used in this study was gathered during site surveys of Aeroport Leopold Sedar Senghor International (Dakar), Senegal (ICAO code: GOOY); Entebbe International Airport, Uganda (ICAO code: HUEN); and Moi International Airport (Mombasa), Kenya (ICAO code: HKMO) in 2005. The corresponding study conducted by Drabek and others was concluded in June of 2006. The executive summary and chapters one (Dakar), four (Entebbe), and nine (Mombasa) are located in the appendices B, C, and D, respectively. Other African airports in Drabek and others' (2006) study that are not included in this paper are Accra, Ghana; Sao Tome; and Nakasongola, Uganda. Data from this report is used to estimate the amount of cargo that can be pushed through each of the three African airports.

The TPFDD used in the Tunisia scenario of ELIST was created in 2002 and was one of the first unclassified TPFDDs released for use in a demonstration model for ELIST (VanGroningen 2009). The Tunisia network in ELIST was likewise built to be an unclassified network that could be used to teach operators how to manipulate the model. Additionally, Braun and VanGroningen's (2003) *ELIST 8 Transportation Model* will be used to highlight ELIST options and possible uses of ELIST for AFRICOM, especially in reference to using an ALN.

Data Format

Drabek and others (2006) has the AST data compiled in a report format which can be viewed in Appendices B through D. The raw AST output is not available.

The Tunisia scenario TPFDD is within the ELIST program itself. The TPFDD can be edited within ELIST, although a dedicated TPFDD editing program is more suitable for major changes (VanGroningen, 2009).   The TPFDD can be extracted in pieces in Microsoft Excel from ELIST. However, it is difficult to comprehend in this manner and doing so adds no relevance to this paper. The example Tunisia TPFDD contains 223 ULNs, 136,501 short tons of cargo, and 38,385 passengers to be moved with a closure time of 49 days. The execution of the Tunisia TPFDD model is examined, but more importantly, this TPFDD is manipulated in various ways to show how AFRICOM can use ELIST for more appropriately sized amounts of cargo and passengers, and how rapidly that cargo can be moved.

Data Assumptions

In examining throughput at the three African airports, several assumptions were made. First, unlimited aircraft are available to bring cargo into the airports. This allows the airport itself to provide the constraints. Cost also is not an issue, as it is assumed that we would be able to maximize the airports use and pay for all fuel necessary and contract all necessary cargo handling equipment and facilities. The model assumes that only equipment on site and contracted to the government or made available by the host nation is available (it does not account for cargo handling equipment that the U.S. might bring in to aid throughput). This is an important assumption, as under the ALN concept, AFRICOM would want to be more reliant on available resources—not additional resources that would need to be deployed. The AST also does not report on passengers, only cargo amounts are considered. The study also only assumed either C-5 or C-17 aircraft (or both) were to be used, and no transloading of cargo from one aircraft to another, which would require additional cargo handling equipment and time, was considered. The AST output in this study also assumed that current commercial operations at the airfields would not be disrupted by military airlift aircraft. In other words, commercial aviation would not give up parking spaces, fuel, or cargo handling equipment that it typically used (Drabek and others, 2003). Operations were assumed to be 24 hours a day seven days a week. Finally, cargo loads for C-17s were 45 tons and C-5s carried 61 tons. Additional assumptions limited to specific airfields will be mentioned in the results section.

ELIST allows the user to manipulate and define many assumptions. However, it does presume that inbound cargo is available at the APOD at a designated time. The Tunisia scenario TPFDD does have passengers, but all manipulations of the TPFDD will eliminate passengers from the TPFDD so that cargo only will be considered. Only road and rail travel are considered in this report, and all intra-theater air travel options are eliminated from ELIST so that they cannot be used for closure. Further assumptions with ELIST will be described with their corresponding outputs in the results chapter.

The following results chapter compiles the AST outputs for Dakar, Entebbe, and Mombasa and also presents multiple ELIST outputs for the Tunisia scenario.

IV. Results

The AST results were released as a June 2006 report for U.S. EUCOM titled "U.S. EUCOM Airfield Throughput Analysis Study for Strategic Airlift" by Drabek and others. Each of the three airfields selected by AFRICOM is reported on separately.

The ELIST results were run from the Tunisia scenario in March of 2006. They are reported along with an explanation of additional options that AFRICOM could select while using ELIST.

Dakar, Senegal

Multiple assumptions were made about Dakar prior to running the AST, and they can be viewed in Appendix B. However, some key assumptions are stated. The airport is busiest from November to March, so the model was run from April to October. Existing commercial throughput is also busiest on Friday, Saturday, and Sunday, so the throughput could be less than that stated on those days. Two parking ramps were used with maximum on ground (MOG) of 3 wide body aircraft (C-5 or C-17). Average inter–arrival time between C-5s and C-17s was two hours. There was assumed to be an unlimited fuel supply from the nearby port. Finally, the simulation was run ten times with each run modeling thirty days of operations.

The AST model found that Dakar could adequately handle ten C-5s and 13 C-17s daily for a throughput of 1195 short tons daily without delay, with a caveat. Dakar typically allows their fuel tanks to settle after filling for 24 hours before filtering water (called fuel settling time). The Defense Energy Support Center stipulates that fuel settling time needs to be between four and 24 hours, so a reduction to four hours would be allowed under U.S. standards. The fueling company at Dakar also would be willing to shorten fuel settling times to four hours, but would require a waiver to be signed allowing them to do so. Without the waiver, military aircraft would begin to encounter delays based on fuel availability. Drabek and others (2006) implied that if there was an operational need, signing this waiver would not be a problem.

Drabek and others (2006) also gave suggestions based on the AST that would allow for even higher throughput and improved airfield operations. These include adding an additional bulk storage tank, repairing several taxiways, improving a parking area, and installing new fueling hydrants. The report also contained numerous pictures taken during the site survey showing conditions of a variety of items on the airfield including cargo downloading equipment, fuel storage and delivery facilities, parking ramps, and multiple other facilities. Finally, Drabek and others (2006) recommended that Dakar be used as a strategic mobility CSL.

Entebbe, Uganda

Far fewer assumptions were listed at Entebbe and the complete list is in Appendix C. Parking MOG was detailed within the report, but no assumptions were stated concerning MOG. Results were based on ten runs that modeled sixty days each.

AST results show that Entebbe could only support a single C-17 flight daily with a 45 ton throughput of cargo. The limiting factor was fuel availability. Fuel has to be trucked in to Uganda from Kenya and takes a minimum of three days for turn time, and there is limited storage at the airfield. AST did report that a surge of four C-17 flights (180 tons of cargo daily) could be sustained for seven days, but then fuel would not be available to continue military operation. Entebbe was not recommended as a CSL candidate by the report. The report also did not discuss the limits of the airfield beyond fuel. There could be potential to increase throughput if aircraft ferried fuel instead of refueling at Entebbe, and then departed to a nearby location such as Nairobi, Kenya to refuel. Like the Dakar report, Entebbe's report also included multiple pictures and additional information on the airfield.

Mombasa, Kenya

All Mombasa assumptions can be viewed in Appendix D. Mombasa was assumed to have an unlimited fuel supply from the nearby port. One parking ramp with a MOG of 3 wide bodied aircraft was used. Mixed C-5/C-17 fleet inter-arrival time of two hours was assumed as well. Averages from 10 runs of the simulation modeling 30 days of operations were used in the analysis.

Either 36 C-17s a day (1620 tons of cargo) or a mix of 18 C-17s and 12 C-5s a day (1542 tons of cargo) could be sustained at Mombasa with no delays. No limiting factors or improvements were listed for Mombasa, and it was recommended as a strategic mobility CSL. As with previous AST reports, this report contained multiple pictures and other airfield information.

ELIST and the Tunisia Scenario.

The ELIST Tunisia scenario and TPFDD was developed as an unclassified model for training and demonstration purposes. It allows a user to both see the output capabilities of ELIST and also to learn how to manipulate the program in order to tailor its output to a given situation. As previously stated, the example TPFDD contains 223 ULNs, 136,501 short tons of cargo, and 38,385 passengers to be moved with a closure time of 49 days from commencement date. To move this TPFDD, the example uses 2818 vehicles of varying types and 180 railcars. Some of these vehicles are in country, while others are part of the TPFDD itself, and once they arrive, they are made available to haul cargo and/or passengers. The initial ELIST Scenario also allows for some intra-theater airlift. However, the air assets were removed so that the scenario would run only with road and rail assets. Each type of vehicle used has to be set up in ELIST. While the demonstration comes with vehicles (including their speeds and carrying capacities) already loaded, they can be manipulated or eliminated from the pool all together, or new vehicles can be added. Likewise, the infrastructure network for Tunisia was preloaded, but ELIST allows for elimination, alteration, and addition of additional routes and nodes should situations change over time. Table 2 shows an ELIST snapshot of the TPFDD, Table 3 shows the vehicle asset pool, and Figure 4 shows the Tunisia network.

Table 2: Sample Section of Tunisian Scenario TPFDD

Row	Seq	RLN	RLN Type	PIC	FIC	UIC	UTC	ULC	Serv	Prov Org	Service Reserved	TPSN	Force Description	Actual Unit Name	Cargo Cat. Code	Supply Class/ Subcl.	STONS	MTONS	CBBLS	Auth Pers	PAX
1	1	00DDA	U: Unit		8		6ZZZZ	HHC	A	7		64ZZZ	HQS HQS CO, SPT BN, ABN				19.1	60	0	95	95
2	1	00DDC	U: Unit		1		6ZZZZ	HHC	A	7		64ZZZ	HQS HQS CO, SPT BN, ABN				203.0	856	0	0	0
3	1	00DDP	U: Unit		2		6ZZZZ	HHC	A	7		64ZZZ	HQS HQS CO, SPT BN, ABN				0.0	0	0	9	9
4	1	00DEA	U: Unit		2		6RB22	HHC	A	7			HHC SIG BDE ABN				0.0	0	0	156	152
5	1	00DEC	U: Unit		1		6RB22	HHC	A	7			HHC SIG BDE ABN				257.8	1348	0	0	0
6	1	00FB	U: Unit		8		0MBNN	HHC	A	7		01082	HHC AIRBORNE DIVISION				66.2	281	0	259	25
7	1	00FC	U: Unit		8		NTCNN	HHC	A	7		01082	HHC/MMC, SPT CMD, ABN DIV				34.9	105	0	187	21
8	1	00FD	U: Unit		8		NTCNN	HHC	A	7		01082	HHC/MMC, SPT CMD, ABN DIV				241.9	1142	0	0	0
9	1	00FDA	U: Unit		8		NTCNN	HHC	A	7		01082	HHC/MMC, SPT CMD, ABN DIV				0.0	0	0	203	20
10	1	00FE	U: Unit		8		3MBNN	HHC	A	7		01082	HHC AIRBORNE BRIGADE				46.2	264	0	89	30
11	1	00FF	U: Unit		8		099BB	HHC	A	7		01082	HHC AIRBORNE DIVISION				0.0	0	0	150	150
12	1	00FG	U: Unit		8		0YSNN	BN	A	7		01082	INF BN ABN				285.9	1389	0	697	517
13	1	00FH	U: Unit		8		0YSNN	BN	A	7		01082	INF BN ABN				163.1	825	0	697	517
14	1	00FJ	U: Unit		8		0YSNN	BN	A	7		01082	INF BN ABN				161.5	827	0	697	517
15	1	00FK	U: Unit		8		1S7NN	BTY	A	7		01082	ADA BTRY VUL/MPDS ABN				32.6	154	0	112	50
16	1	00FL	U: Unit		8		1S7NN	BTY	A	7		01082	ADA BTRY VUL/MPDS ABN				63.2	388	0	112	17
17	1	00FQ	U: Unit		8		QXTTT	CO	A	7		01082	MP COMPANY AIRBORNE DIV				24.2	87	0	98	21
18	1	00FR	U: Unit		8		QXTTT	CO	A	7		01082	MP COMPANY AIRBORNE DIV				26.9	109	0	98	5
19	1	00FS	U: Unit		8		6D444	CO	A	7		01082	FWD COMM CO ABN				0.1	1	0	183	15
20	1	00FTC	U: Unit		8		6D444	CO	A	7		01082	FWD COMM CO ABN				44.9	179	0	183	0
21	1	00FTP	U: Unit		2		6D444	CO	A	7		01082	FWD COMM CO ABN				0.0	0	0	183	10
22	1	00FV	U: Unit		8		44RNN	CO	A	7		01082	ENGR CO, ENGR BN, ABN DIV				227.2	604	0	0	0
23	1	00FVA	U: Unit		2		44RNN	CO	A	7		01082	ENGR CO, ENGR BN, ABN DIV				0.0	0	0	94	94
24	1	00GB	U: Unit		8		PC4NN	CO	A	7		01082	C J CO MI BN ABN DIV				19.4	48	0	113	12
25	1	00GC	U: Unit		8		PC4NN	CO	A	7		01082	C J CO MI BN ABN DIV				27.5	113	0	113	11
26	1	00GDC	U: Unit		8		2AAFF	CO	A	7		01082	AR CO AR BN ABN DIV/SEPBD				19.1	60	0	0	0
27	1	00GDP	U: Unit		8		2AAFF	CO	A	7		01082	AR CO AR BN ABN DIV/SEPBD				0.0	0	0	86	20
28	1	00GE	U: Unit		8		JH5NN	CO	A	7		01082	FWD SUP CO S T BN ABN DIV				21.4	65	0	56	23
29	1	00GF	U: Unit		8		JH5NN	CO	A	7		01082	FWD SUP CO S T BN ABN DIV				102.9	380	0	0	0
30	1	00GFA	U: Unit		2		JH5NN	CO	A	7		01082	FWD SUP CO S T BN ABN DIV				0.0	0	0	57	46
31	1	00GG	U: Unit		8		F3WNN	CO	A	7		01082	FWD SPT MEDICAL CO ABN				22.2	115	0	68	43
32	1	00GH	U: Unit		8		F3WNN	CO	A	7		01082	FWD SPT MEDICAL CO ABN				69.4	416	0	0	0
33	1	00GHA	U: Unit		2		F3WNN	CO	A	7		01082	FWD SPT MEDICAL CO ABN				0.0	0	0	68	63

Table 3: Tunisia Scenario Ground Movement Assets

Vehicles and Service Area for Asset Pool: **BIZERTE DD**

Vehicles

Row	Priority	Pool	Vehicle	Num	Start Day	End Day	% Avail	Num Avail
1	0	BIZERTE DD	M1088 WOWN MTV Tractor/M967A1 5000-Gal Tanker	60	22.04		100.0	60
2	0	BIZERTE DD	M1088 WOWN MTV Tractor/M967A1 5000-Gal Tanker	60	22.79		100.0	60
3	0	BIZERTE DD	M915A2 25-Ton Tractor/M872A3 34-Ton Semitrailer	61	24.04		100.0	61
4	0	BIZERTE DD	M1088 WOWN MTV Tractor/M967A1 5000-Gal Tanker	60	24.79		100.0	60
5	0	BIZERTE DD	M1088 WOWN MTV Tractor/M967A1 5000-Gal Tanker	60	25.04		100.0	60
6	0	BIZERTE DD	M1088 WOWN MTV Tractor/M967A1 5000-Gal Tanker	60	25.29		100.0	60
7	0	BIZERTE DD	M1088 WOWN MTV Tractor/M967A1 5000-Gal Tanker	60	25.54		100.0	60
8	0	BIZERTE DD	M915A2 25-Ton Tractor/M872A3 34-Ton Semitrailer	61	26.04		100.0	61
9	0	BIZERTE DD	M1083 WOWN 5-Ton MTV	52	26.29		100.0	52
10	0	BIZERTE DD	M1088 WOWN MTV Tractor/M871A2 22.5-Ton Semitrailer	10	26.29		100.0	10
11	0	BIZERTE DD	M915A2 25-Ton Tractor/M872A3 34-Ton Semitrailer	61	27.04		100.0	61
12	0	BIZERTE DD	M915A2 25-Ton Tractor/M872A3 34-Ton Semitrailer	61	28.29		100.0	61
13	0	BIZERTE DD	M915A2 25-Ton Tractor/M872A3 34-Ton Semitrailer	61	28.79		100.0	61
14	0	BIZERTE DD	M915A2 25-Ton Tractor/M872A3 34-Ton Semitrailer	61	29.04		100.0	61
15	0	BIZERTE DD	M1070 HET Tractor/M1000 70-Ton HET Trailer	96	34.80		100.0	96
16	0	BIZERTE DD	M1070 HET Tractor/M1000 70-Ton HET Trailer	96	39.28		100.0	96
17	0	BIZERTE DD	M1070 HET Tractor/M1000 70-Ton HET Trailer	96	41.31		100.0	96
18	1	BIZERTE DD	commercial heavy railcar	200			90.0	180
19	2	BIZERTE DD	M1088 WOWN MTV Tractor/M967A1 5000-Gal Tanker	120			90.0	108
20	3	BIZERTE DD	M1074 PLS	75			90.0	67
21	4	BIZERTE DD	M1083 WOWN 5-Ton MTV	240			90.0	216
22	5	BIZERTE DD	M1083 WOWN 5-Ton MTV	180			90.0	162
23	6	BIZERTE DD	M35 2.5-Ton	320			90.0	288
24	7	BIZERTE DD	Commercial POL Truck	60			95.0	57
25	8	BIZERTE DD	Commercial Bus 45-pax	320			95.0	304
26	9	BIZERTE DD	Commercial 10-Ton Tractor/Commercial Semitrailer	240			90.0	216
27	10	BIZERTE DD	M123 10-Ton Tractor/M870 40-Ton Lowbed	120			90.0	108
28	11	BIZERTE DD	Commercial HET Tractor/Commercial HET Trailer	60			90.0	54
29	12	BIZERTE DD	M1070 HET Tractor/M1000 70-Ton HET Trailer	120			90.0	108
30	13	BIZERTE DD	Commercial HET Tractor/Commercial HET Trailer	60			90.0	54

As set up, with no further alteration other than the elimination of intra-theater airlift, the Tunisia Scenario takes 49 days. However, in the first 20 days from commencement, almost zero assets are moved because they do not arrive in theater (a TPFDD is set up from a commencement date, and in this case, the first 20 days are used to move the assets from the U.S. into Tunisia or Algeria). Thus, realistically, this entire movement is completed in 29 days in terms of intra-theater movement (Figure 5 shows vehicle usage and assets). However, only 8.1% of cargo and 69.8% of passengers arrive at their destination on time (Table 4 gives a graphical representation of late cargo taken from ELIST).

Figure 4: Tunisia ELIST Network

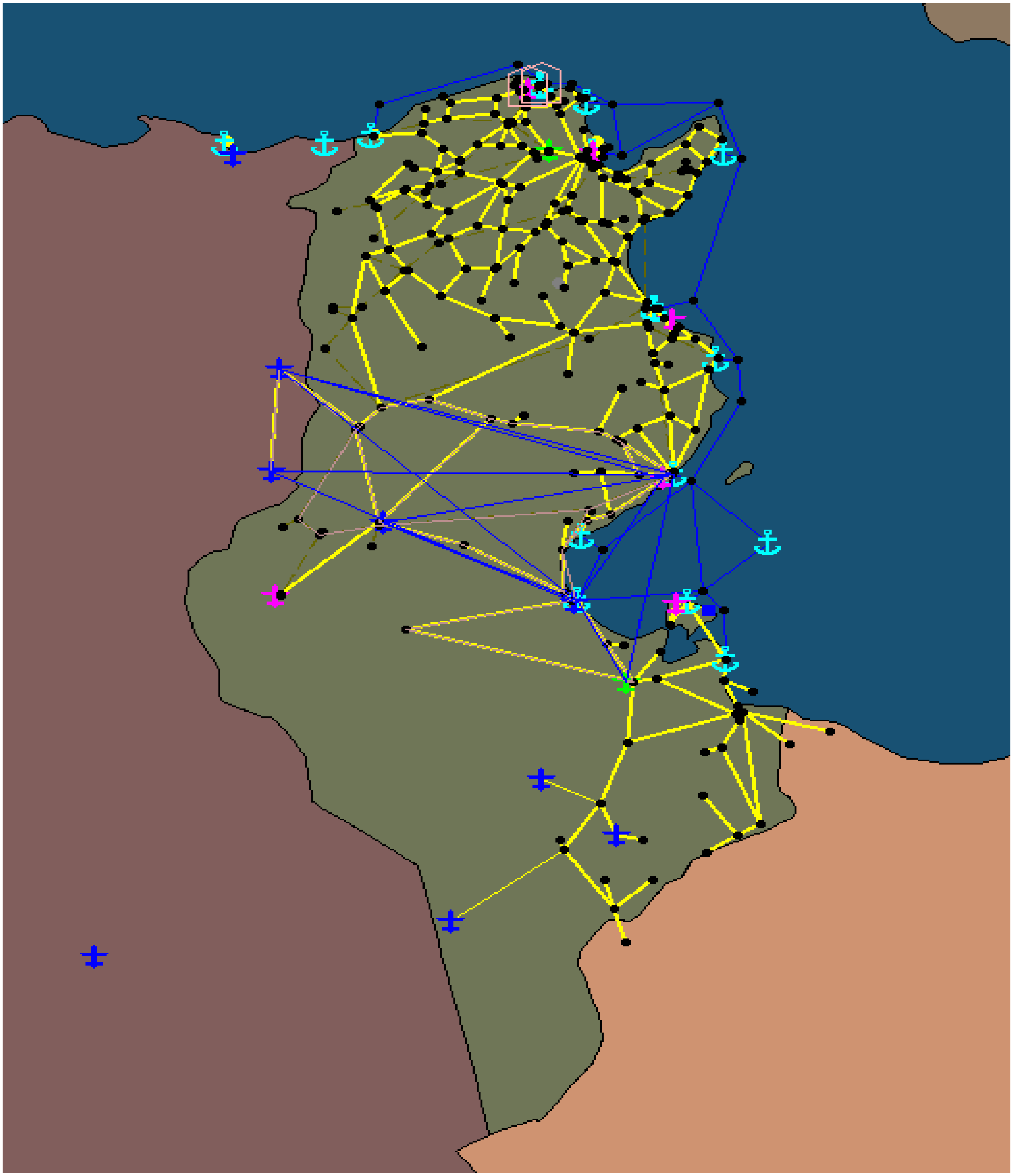


Table 4: Cargo and Passenger Closure with Delays

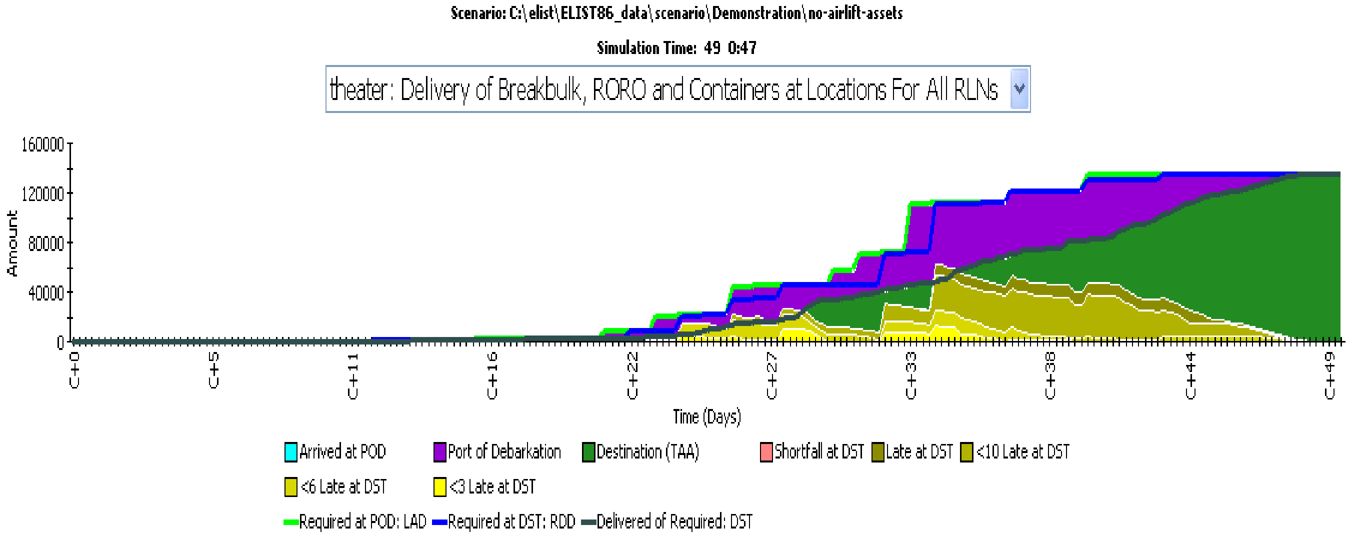
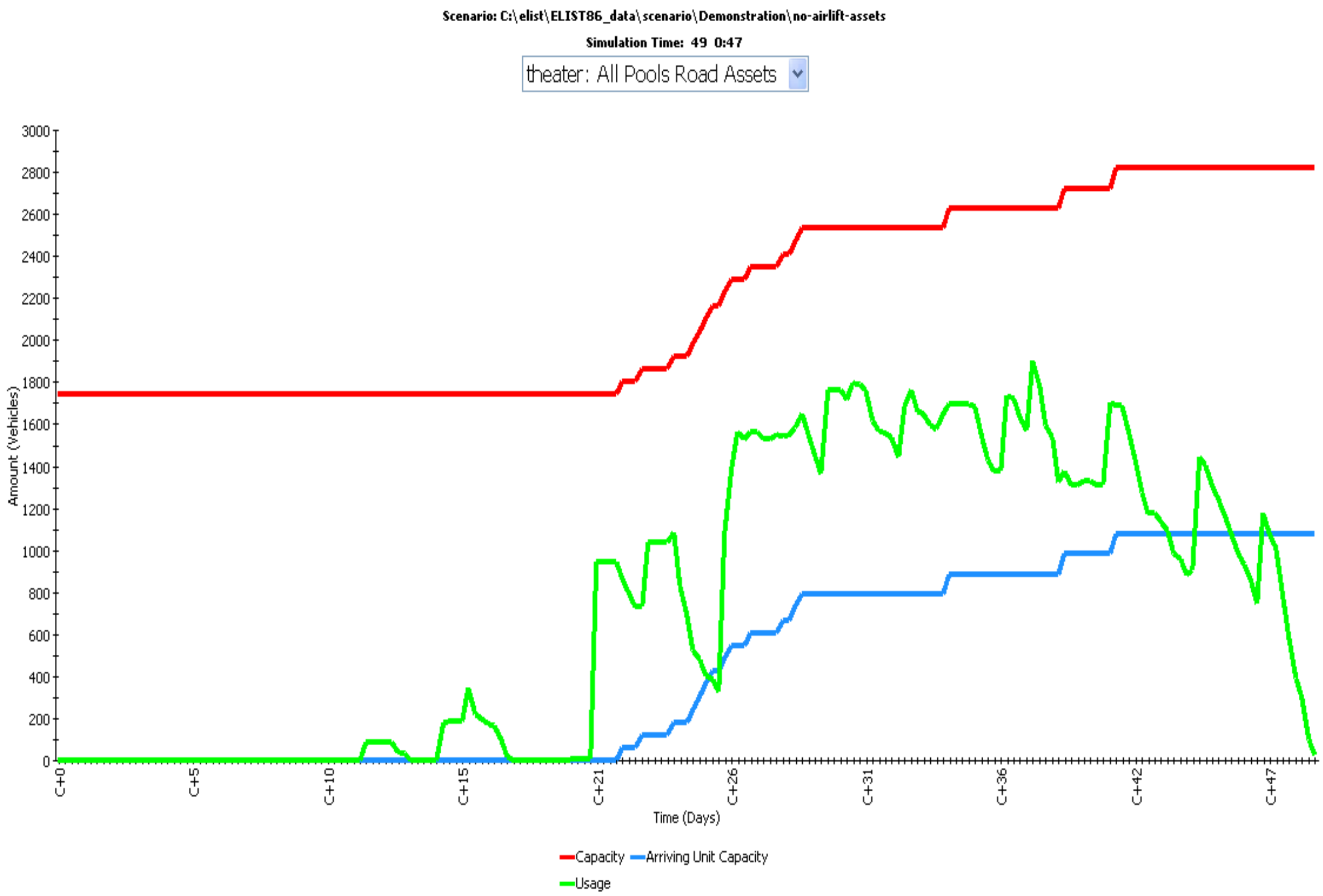


Figure 5: Vehicle Usage in Tunisia Scenario



ELIST also summarizes what types of vehicles, as well as what routes, are constraints on its solution. This allows the planner to see if they need more vehicles, or perhaps see what road is maxed out with traffic. For example, M871A2 22.5 ton semi-trailers were used for 14 days at over 90% capacity, and had an average use of 83.9%. These semi-trailers were part of the TPFDD. The simulation could potentially be used to examine adding more of these semi-trailers to the TPFDD. Table 5 shows a screen shot sample of the constraints data.

Table 5: Sample of Tunisia Scenario Constraints

Constraints ☑ Queues ☐ Route Links

Row	Queue	The...	First Used	Last Used	First Queued	Last Queued	Max Inter... Use (%)	Intervals Used Over 90% of Capacity	Ave Interval Use (%)	Max Day Use (%)	Days Used Over 90% of Capacity	Days with Waiting Carry-Over
1	BIZERTE DD Asset Commercial Bus 45-pax	thea...	12 0:00	40 8:48	12 0:00	40 6:00	90.1	0	13.9	88.8	0	12
2	BIZERTE DD Asset M35 2.5-Ton	thea...	12 0:00	48 1:23	12 0:00	47 12:00	100.0	29	38.1	100.0	7	27
3	BIZERTE DD Asset M1083 WOWN 5-Ton MTV	thea...	12 0:00	48 9:34	12 0:00	47 12:00	100.0	40	58.9	100.0	10	29
4	BIZERTE DD Asset M1088 WOWN MTV Tractor/M871A2 22.5-Ton Semitrailer	thea...	26 12:00	46 12...	12 0:00	47 12:00	100.0	64	83.9	100.0	14	29
5	BIZERTE DD Asset Commercial 10-Ton Tractor/Commercial Semitrailer	thea...	16 0:00	48 12...	12 0:00	47 12:00	100.0	44	56.6	100.0	10	30
6	BIZERTE DD Asset M1070 HET Tractor/M1000 70-Ton HET Trailer	thea...	15 0:00	47 21...	12 0:00	47 12:00	100.0	60	67.3	100.0	12	27
7	BIZERTE DD Asset Commercial HET Tractor/Commercial HET Trailer	thea...	16 0:00	47 14...	12 0:00	47 12:00	100.0	61	69.0	100.0	13	30
8	BIZERTE DD Asset M123 10-Ton Tractor/M870 40-Ton Lowbed	thea...	21 0:00	48 15...	12 0:00	47 12:00	100.0	40	68.3	100.0	8	29
9	BIZERTE DD Asset M915A2 25-Ton Tractor/M872A3 34-Ton Semitrailer	thea...	26 6:00	48 18...	12 0:00	47 12:00	100.0	40	69.4	100.0	9	29
10	BIZERTE DD Asset M1074 PLS	thea...	23 0:00	45 9:48	12 0:00	47 12:00	100.0	20	47.9	100.0	4	27
11	Auto Commodity	thea...			15 0:00	46 0:00						27
12	Road Route from BIZERTE -BSRL-PRT to GABES -HNTS-PRT	thea...	12 0:00	38 6:00	15 0:00	23 6:00	25.0					2
13	Road Route from BIZERTE -BSRL-PRT to GABES -HNTS-PRT	thea...	21 12:00	23 6:00	15 0:00	23 6:00	25.0					2
14	Road Route from THYNA -FUQN-IAP to CHEIKH LARBI TEBE -WSVC-CAP	thea...	12 12:00	40 6:00	15 12...	38 12:00	24.2					2
15	Road Route from BIZERTE -BSRL-PRT to THYNA -FUQN-IAP	thea...	12 0:00	32 0:00	16 0:00	26 18:00	25.0					0
16	Road Route from CHEIKH LARBI TEBE -WSVC-CAP to GABES -HNTS-PRT	thea...	15 0:00	42 6:00	21 0:00	39 6:00	25.0					4
17	Road Route from CHEIKH LARBI TEBE -WSVC-CAP to GABES -HNTS-PRT	thea...	27 12:00	28 12...	21 0:00	39 6:00	7.0					4
18	Road Route from CHEIKH LARBI TEBE -WSVC-CAP to GABES -HNTK-APT	thea...	23 18:00	47 6:00	21 0:00	42 6:00	24.7					3
19	Road Route from GABES -HNTS-PRT to GABES -HNTM-CTY	thea...	21 18:00	48 18...	21 18...	48 18:00	25.0					5
20	GABES -HNTS-PRT Loaded Vehicles for Road	thea...	12 20:03	48 12...	22 12...	46 6:00	100.0	32	45.1	100.0	6	25
21	Road Route from GABES -HNTM-CTY to GABES -HNTS-PRT	thea...	22 0:00	48 6:00	23 0:00	48 6:00	25.0					8
22	Road Route from GABES -HNTM-CTY to THYNA -FUQN-IAP	thea...	25 0:00	28 6:00	24 0:00	28 0:00	9.1					3
23	Road Route from GABES -HNTK-APT to GABES -HNTM-CTY	thea...	24 6:00	48 0:00	24 6:00	25 0:00	15.2					0
24	Road Route from GABES -HNTK-APT to GABES -HNTM-CTY	thea...	24 6:00	47 18...	24 6:00	25 0:00	15.2					0
25	Road Route from GABES -HNTM-CTY to MERSA SFAX -VKNP-PRT	thea...	26 0:00	26 6:00	26 0:00	27 6:00	15.9					1
26	Road Route from GABES -HNTM-CTY to MERSA SFAX -VKNP-PRT	thea...	26 6:00	33 0:00	26 0:00	27 6:00	25.0					1
27	Road Route from BIZERTE -BSRL-PRT to GABES -HNTK-APT	thea...	25 0:00	32 0:00	26 0:00	26 12:00	2.1					0
28	Road Route from BIZERTE -BSRL-PRT to GABES -HNTK-APT	thea...			26 0:00	26 12:00	0.0					0
29	Road Route from GABES -HNTK-APT to GAFSA -HPBF-APT	thea...	25 0:00	39 18...	26 0:00	39 18:00	8.7					4
30	Road Route from MERSA SFAX -VKNP-PRT to CHEIKH LARBI TEBE -WSVC-CAP	thea...	12 12:00	48 12...	26 12...	48 12:00	25.0					3
31	Road Route from GABES -HNTS-PRT to CHEIKH LARBI TEBE -WSVC-CAP	thea...	12 18:00	44 6:00	26 12...	41 18:00	23.3					6
32	Road Route from GABES -HNTS-PRT to CHEIKH LARBI TEBE -WSVC-CAP	thea...	27 6:00	47 0:00	26 12...	46 18:00	25.0					7
33	Road Route from MERSA SFAX -VKNP-PRT to BIR EL ATER -BQWK-APT	thea...	26 12:00	33 12...	27 0:00	33 12:00	24.1					5
34	Road Route from CHEIKH LARBI TEBE -WSVC-CAP to MERSA SFAX -VKNP-PRT	thea...	26 0:00	47 0:00	27 6:00	45 0:00	25.0					5
35	Road Route from CHEIKH LARBI TEBE -WSVC-CAP to MERSA SFAX -VKNP-PRT	thea...	27 12:00	27 12...	27 6:00	45 0:00	0.6					5
36	Road Route from GABES -HNTK-APT to BIR EL ATER -BQWK-APT	thea...	24 6:00	39 18...	27 6:00	39 18:00	5.5					3
37	MERSA SFAX -VKNP-PRT Loaded Vehicles for Road	thea...	12 14:29	48 6:00	28 0:00	47 12:00	100.0	41	39.7	100.0	10	12

This overview of the Tunisia Scenario and TPFDD is a very small example of the detail that ELIST simulates and allows planners to explore. ELIST additionally allows users to set the percentage of a truck/railcar that has to be used prior to shipment, how long that car will wait to get full, how many railcars per train, the rate of travel per hour for all assets, loading times, individual road weight limits, and multiple other factors (the default settings were used for the above Tunisia scenario). Individual bridges can be "damaged" at a given time during the simulation to force the model to work around a certain route, or routes can likewise add capacity at a certain time during the simulation (if for example combat engineers are part of the deployment and made improvements to a route). Airports and seaports can be constrained to only allow so much cargo to be stored or throughput. This gives the user an enormous amount of control, but also creates an enormous amount of complexity. Any planner attempting to use the software should be trained on its use by personnel from Argonne National Laboratory. As previously stated, the output of any model is only as good as the data that is input into that model.

The Tunisia TPFDD moves a large amount of equipment (136,501 short tons of cargo, and 38,385 passengers). On a day to day basis, AFRICOM is looking at moving a much smaller amount, and also having drastically less resources to move the cargo once it is in theater. AFRICOM planners would simply need to load their own TPFDD and set the vehicle capabilities to what they would realistically have at their disposal. As an example, all RLNs from the Tunisia TPFDD were removed except one that contained 203 tons of cargo, or roughly 5 C-17s loads of cargo. The point of debarkation for this RLN was changed to Bizerte's Airport (Geolocation: BSRR), and the destination changed to Gabes (Geolocation: HNTM) to create a 321 mile trip. Then, vehicle assets were adjusted so that only one ten-ton commercial truck could be used to move the cargo. It took eight loads of 25.38 tons per load and 13 days to move the cargo that distance. Each trip takes 0.86 days travel time. By changing the available trucks to eight, the move is completed in a single day with no constraints on the road network. Thus, to move this TPFDD cargo and allow it to arrive in a single day, AFRICOM would want to contract a local carrier that had at least eight ten-ton semi-trucks available for use. By tailoring ELIST to the requirements, AFRICOM can answer the second question of how far it can move cargo in a given number of days, or how long until it can expect to achieve closure on a TPFDD given a certain vehicle asset pool at its disposal. AFRICOM can even incorporate intra-theater airlift, if it has assets at its disposal (either contract or military). Tables 6, 7, and 8 and Figure 6 provide ELIST inputs and outputs for this scenario.

Table 6: RLN for Single Line TPFDD Scenario

Movement Requirements: JOPES Table

Unit Cargo Movement Additional Movement Marry Up MIDAS

Row	Seq	RLN	..	..	..	POD On Call	On Hold	..	...	..	...	..	..	...	..	..	EAD	LAD	Mode/ Source to POD	..	..	POD	P... CSC	POD Delay	RDD	Mode/ Source to DST	Dest	DEST CSC	..	..	POD Arrival Priority	..	STONS
1	1	00DDC	..			☐	☐	8	..	..	...	...	..	..	..	...	1	3	SE			**BSRR**	TS	0.0	3	LD	**HNTM**	TS			002		203.0

Figure 6: Delivery Closure with Eight Commercial Trucks

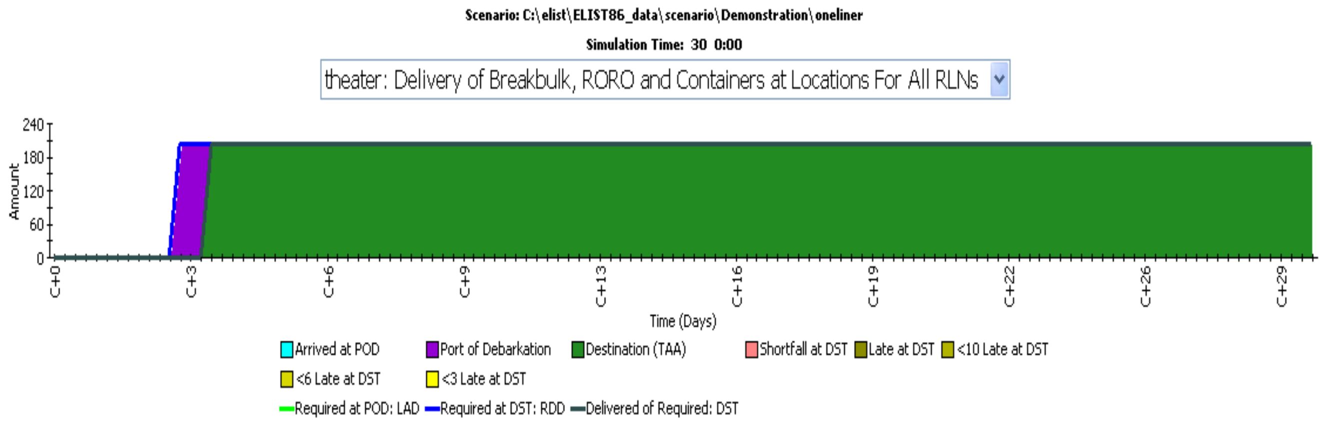


Table 7: Delivery Statistics for Eight Commercial Truck Scenario

Scenario: C:\elist\ELIST86_data\scenario\Demonstration\oneliner

Simulation Time: 30 0:00

Asset Use Statistics

Row	Pool	Vehicle	Max Vehs Avail	Num Loaded Trips	Num Empty Trips	Num Wasted Trips	Ave Miles Loaded Trips	Ave Miles Empty Trips	Ave ST	Ave PAX	Ave Cbbl POL
1	BIZERTE DD	Commercial 10-Ton Tractor/Commercial Semitrailer	8	8	8	0	321.08	8.58	25.38	0.00	0.00

Table 8: Cargo Flow from APOD to Destination

Scenario: C:\elist\ELIST86_data\scenario\Demonstration\oneliner

Simulation Time: 30 0:00

theater: 1:00DDC UTC:6ZZZZ UIC:null

Commodity	Detail	Amount	ST	Sq Ft	CCC	Description	Time	Req Day	Event	Location
Oversized Tonnage -BB	#1:00DDC.OVR	16.30	16.30	0.00	OVR		3 0:00	3	Available	SIDI AHMED AIR BA -BSRR-IAF
							3 0:00		Waiting for BIZERTE DD Asset Commercial 10-Ton Tractor/Commercial Semitrailer	SIDI AHMED AIR BA -BSRR-IAF
							3 1:06	3	Select Mode	SIDI AHMED AIR BA -BSRR-IAF
							3 2:06	3	Road Onloading	SIDI AHMED AIR BA -BSRR-IAF
							3 2:06	3	Road Departure (Commercial 10-Ton Tractor/Commercial Semitrailer:8 BIZERTE DD)	SIDI AHMED AIR BA -BSRR-IAF
							3 22:46	3	Road Arrival (Commercial 10-Ton Tractor/Commercial Semitrailer:8 BIZERTE DD)	GABES -HNTM-CTY
							3 22:46	3	Entering Node (Commercial 10-Ton Tractor/Commercial Semitrailer:8 BIZERTE DD)	GABES -HNTM-CTY
							3 23:46	3	Road Offloading	GABES -HNTM-CTY
							3 23:46	3	Final Delivery	GABES -HNTM-CTY
Oversized Tonnage -BB	#1:00DDC.OVR	150.00	150.00	0.00	OVR		3 0:00	3	Available	SIDI AHMED AIR BA -BSRR-IAF
							3 0:00		Waiting for BIZERTE DD Asset Commercial 10-Ton Tractor/Commercial Semitrailer	SIDI AHMED AIR BA -BSRR-IAF
							3 0:33	3	Select Mode	SIDI AHMED AIR BA -BSRR-IAF
							3 1:33	3	Road Onloading	SIDI AHMED AIR BA -BSRR-IAF
							3 1:33	3	Road Departure (Commercial 10-Ton Tractor/Commercial Semitrailer:3 BIZERTE DD+4)	SIDI AHMED AIR BA -BSRR-IAF
							3 22:13	3	Road Arrival (Commercial 10-Ton Tractor/Commercial Semitrailer:3 BIZERTE DD+4)	GABES -HNTM-CTY
							3 22:13	3	Entering Node (Commercial 10-Ton Tractor/Commercial Semitrailer:3 BIZERTE DD+4)	GABES -HNTM-CTY
							3 23:13	3	Road Offloading	GABES -HNTM-CTY
							3 23:13	3	Final Delivery	GABES -HNTM-CTY

ELIST completely enables AFRICOM's ALN concept. However, AFRICOM needs to know what resources are available in each location that they are interested in using. Once they have determined what contractors are available to move cargo, they need to build an asset pool with the vehicles that those contractors can provide at each location. If needed, ELIST allows planners to task certain pieces of cargo to only be carried by certain vehicle types. As a further step, vehicles can be assigned to be used only for certain distances. For example, a commercial ten-ton semi-truck can only be used if the distance to move is over 50 miles. ELIST can also assign certain cargo for direct delivery, or linehaul, if that is a specific requirement that AFRICOM desires. Certain cargo can be assigned a specific route, if that is necessary (such as hazardous cargo only being allowed to travel on certain roads). Cargo and passengers can also be forced to marry up at a certain location prior to moving on to the final destination. Once AFRICOM's logistics planners fully understand ELIST, it can be as adapted to model any network they wish it to model.

V. Recommendations and Conclusion

Recommendations

The following four recommendations are based on the results of this study.

Recommendation One. AFRICOM needs to determine which African airports it wants to study. Then, information and model inputs would have to be collected in order for studies to be conducted using AST. It was by sheer chance that the three airfields that AFICOM wanted throughput information for were already examined by Drabek and others 2006 EUCOM study. Only five of ten airfields in the study were located in Africa, so it was fortuitous that all three selected fields had already been examined using AST. The other two fields that have been researched are Sao Tome International Airport (ICAO: FPST), Sao Tome and Principe, and Nakasongola Airfield (no ICAO identifier), Uganda. According to Norm Drabek (2009), an analyst for Joint Distribution Process Analysis Center (JDPAC) (and the author of the EUCOM study), it takes six weeks minimum for a report on an airfield to be completed. This includes travel time to get to the site and return to Scott Air Force Base, time to conduct a thorough site survey, and time to run that data through AST and generate the resultant report. That is if 100 percent of his efforts are focused on creating the report. Obviously, with such time requirements, AFRICOM needs to carefully choose which sites it wants JDPAC to analyze, and possibly come up with a strategy to implement over time to get coverage over its enormous AOR. AFRICOM is also completely reliant on TRANSCOM for the use of wide-bodied military strategic airlift aircraft (C-5s and C-17s). However, they do have two C-130 aircraft assigned to them with the potential for more to come in the future. Thus, they may want C-130 aircraft to be included in AST's simulation as well as wide bodied aircraft, especially if they are choosing to analyze smaller airfields that may not be properly equipped to handle wide-bodied aircraft.

Recommendation Two. AFRICOM needs to acquire ELIST for their use, as well as have logistics planners properly trained to use it. When this study was being formulated in the fall of 2008, AFRICOM was not even officially a geographical Combatant Command. The AFRICOM DDOC was still in the process of standing up, and they were not using any type of mobility modeling software. However, as of February 2009, AFRICOM logistics planners do have ELIST software. The next step is to ensure that the Logistics planners are properly trained. ELIST is an extremely detailed simulation model, and requires expert users to produce meaningful results. Simulations run for this study were very simple in nature and were meant to show the possibilities of ELIST, but by no means tapped into its power. Also, by the very nature of using an ALN, AFRICOM is going to need to understand the complexities of ELIST in order to get realistic simulations. ELIST has the power to accurately simulate an ALN, but the model can only be useful if it has the proper inputs. Argonne National Laboratory, the developer of ELIST, has personnel that instruct users on ELIST's proper use, and they should be employed by AFRICOM to visit the logistics planners in Stuttgart and address AFRICOM specific questions so that the AOR can be properly simulated.

Recommendation Three. At this time, the entire AFRICOM AOR was not networked by ELIST. The Army component of TRANSCOM, the Surface Deployment and Distribution Command (SDDC) has the responsibility to populate the African ELIST network. Portions of the AOR are networked and this network itself makes the software classified, as well as any outputs created using the classified network. AFRICOM needs to work hand in hand with SDDC to ensure that the African network is populated in the proper sequence so that areas of concern are the first to be networked. AFRICOM also has to start conducting site surveys and working with local African transportation contractors. For each location, AFRICOM needs to acquire information on what type and how many vehicles could be used to move cargo and passengers that arrive at a particular APOD. This information is vital to build an accurate asset pool for that location and allow ELIST to provide meaningful results. As with all models, inaccurate information fed to the model would create inaccurate results (often known as “garbage in equals garbage out”). This information also needs to be continuously updated within the model as both networks and asset pools change over time.

Recommendation Four. Finally, AFRICOM planners need to approach modeling with a certain caution. A model is always an abstraction of the real world, and no model is 100% accurate. A model should not be taken too literally, or pressed to do what it was not designed to do (Ravindran and others, 1987). Caution is also warranted on overselling a model or its output. Models are simply tools used to increase planning accuracy, and to reduce risks associated with military logistics plans.

AFRICOM also needs to look within its AOR to specifically understand what principles or situations the AST and ELIST models do not cover. Two that are specific to Africa are theft and lost cargo due to accidents or damages from rough roads. ELIST does not account for either, and many portions of Africa are susceptible to both. ELIST can aid planners in certain aspects to reduce theft. For instance, direct delivery may reduce occurrences of theft over linehaul trucking, where more players and cargo handling come into play. However, ELIST assumes what is loaded at an APOD will eventually get to its final destination.

Limitations of this Study

The AST portion of this study was based on site surveys done in 2005 and then reported on in 2006. Multiple improvements to the three airfields investigated could have occurred during this four year time span. Likewise, airfields, material handling equipment, and fueling equipment could also have been damaged or become inoperable. The accuracy of AST outputs will always fade with respect to the time the site survey was accomplished, and to maintain their accuracy, follow up site studies should be planned on a regular basis.

The ELIST portion of this study had several limitations. First, the only accessible ELIST software and network that was made available to the author was the Tunisia demonstration model. While the Tunisia scenario and TPFDD shows the capabilities that ELIST can simulate, it obviously could not model cargo flow out of Dakar, Entebbe, or Mombasa. As previously mentioned, these areas may be networked for ELIST, but if they are, it is classified in nature as would be the output. The TPFDD itself was also difficult to manipulate within ELIST, so it was somewhat difficult to model a smaller one line RLN and make it cargo only and of a relevant size.

The greatest limitation concerning ELIST and its use in this study was probably the author’s limited knowledge of how to use the program. Charles VanGroningen of Argonne National Laboratory generously spent an hour of his time teaching me the basics of ELIST and also provided me with basic user manuals. However, ELIST is extremely complex, and normally one to two full days of instruction are provided to logistics planners who will use the program for simulation. These logistics planners are also typically more savvy on editing TPFDDs and the deployment and distribution process than was the author. Recognizing this limitation, all ELIST simulations performed were of a very simple nature with a focus of showing the basic characteristics of the program, and then using the user's manuals to discuss additional capabilities of the software.

Finally, this study looked very specifically at intra-theater movements by road or rail only with an airport as the origin. Inter-theater or strategic movements can also be extremely complex and multiple models such as Model for Inter-theater Deployment by Air and Sea (MIDAS) and the Joint Flow and Analysis System for Transportation (JFAST) can be used to simulate this stage of deployment. The AMP Federation of models also has several seaport simulators including the Seaport Throughput Tool (STT), the Seaport Rapid Analysis Tool (SRAT), and the Seaport Simulation Tool (SST), that can be used to examine seaport throughput.

Areas for Further Study

Many areas for further study relate to the previously mentioned limitations. As AFRICOM planners create operational plans and TPFDDs, they will need to be tested at the strategic mobility level. A study showing the usefulness of either MIDAS or JFAST, and comparing which of the two might show more promise for AFRICOM use would show the way for door to door modeling. Similarly, instead of modeling African airports, a similar study could look at modeling seaports for and compare results from SST, STT, and SRAT to determine the most useful tool for AFRICOM on this front. Finally, a more in depth study of ELIST on the classified level could be run using actual TPFDDs that have been developed by AFRICOM. Another potential ELIST study could be comparing an ELIST simulation and its associated TPFDD to an African exercise where the TPFDD was actually executed to compare the simulated ELIST results to the actual exercise results, and thus verify ELIST's use in Africa. Finally, Africa Command's focus on leveraging the logistics capability of host and partner nations, and interagency and non-governmental organizations adds another element. How the command integrates and incorporates these logistics capabilities is another area for future study.

Conclusion

This paper's intent was to help AFRICOM answer questions concerning airport cargo throughput and cargo movements via road and rail within its AOR. The difficulties inherent in moving cargo in Africa's underdeveloped infrastructure combined with the ever developing strategic importance of Africa have created a dilemma of some sorts for AFRICOM, the United States' newest Combatant Command. To overcome this difficulty, AFRICOM is hoping to leverage cooperative security locations, as well as an adaptive logistics network to either use prepositioned assets to aid in cargo movement or adapt to the assets that are in place in theater and use those assets to move cargo. An ALN goes against traditional philosophies that the military and its own assets move its own cargo, but is much more applicable to AFRICOM due to its force size limitations and desire to maintain a small footprint in Africa.

The remainder of the paper focused on how AFRICOM could use mobility models to answer its how much and how far questions. Both the APOD and ELIST models fall under the Analysis of Mobility (AMP) federation of models. The Airport Simulation Tool, or AST, is one portion of APOD, and it can be used to measure cargo throughput at a particular field given multiple inputs such as parking areas, fuel storage facilities, fuel delivery equipment, and material handling equipment. AST input and outputs are typically released as a study allowing potential planners to estimate how many aircraft can flow into and out of an airport, and thus measure how much cargo can be pushed through that airfield. Limiting factors are also identified.

ELIST models how that cargo is flowed from an arrival port of debarkation, such as an airport, to its final destination. While ELIST is capable of modeling waterways, pipelines, helicopter and intratheater airlift, the focus of this study was on the use of roads and railroads, which are the most common means of cargo movement in Africa. While AST instances are usually run by the Joint Distribution Process Analysis Center at Scott Air Force Base, ELIST software can be used directly by AFRICOM logistics planners. ELIST takes a TPFDD, and simulates its dispersion using a developed network that matches a location's road and rail network and that location's asset pool of vehicles. The simulation shows how long it takes to move cargo to its required destination, details if it arrived on time or is late (according to the TPFDD timeline), and shows the limiting constraints, be it vehicles or the road/rail network itself.

The combination of these two models can give AFRICOM an estimation of the in place African distribution network and show weak points that perhaps require aid in developing. It also allows AFRICOM to realistically measure the viability of its operational deployment plans and movements of day to day cargo. ELIST's adaptability, in particular, allows logistics planners to see if an ALN can be realistically used in various portions of Africa. However, as with all models, inputs need to be precise in order to get meaningful, insightful outputs. AFRICOM needs to ensure that its ELIST planners are properly trained, and they need to be able to recognize the models limitations, especially as these limitations relate to the AFRICOM AOR.

Glossary

AFRICOM – African Command

AGOA – African Growth and Opportunity Act

ALN – Adaptive Logistics Network

AMP – Analysis of Mobility Platform

AOR – Area of Responsibility

APOD – Aerial Port of Debarkation

AMC – Air Mobility Command

ASAM – Advanced Study of Air Mobility

AST – Airport Simulation Tool

BPR – Business Process Reengineering

CENTCOM – Central Command

COCOM – Unified Combatant Command

CRS – Congressional Research Service

CSL – Cooperative Security Location

DDOC – Deployment and Distribution Operations Center

DOD – Department of Defense

DST – Destination

ELIST – Enhanced Logistics Intra-theater Support Tool

EAD – Earliest Arrival Date in theater

ETPFDD – Expanded Time Phased Force Deployment Data

EUCOM – European Command

GIS – Geographical Information System

GDP – gross domestic product

GRP – Graduate Research Project

ICAO – International Civil Aviation Organization

JFAST – Joint Flow and Analysis System for Transportation

JDPAC – Joint Distribution Process Analysis Center

LAD – Latest Arrival Date in theater

MIDAS – Model for Inter-theater Deployment by Air and Sea

MOG – maximum on ground

NATO – North Atlantic Treaty Organization

NGO – Non-Governmental Organization

PACOM – Pacific Command

PEPFAR – U.S. President's Emergency Plan for AIDS Relief

RLD – Ready to Load Date in theater

RLN – Requirement Line Number

RSO&I – Reception, Staging, Onward Movement, and Integration

SDDC – Surface Deployment and Distribution Command

SRAT – Seaport Rapid Analysis Tool

SST – Seaport Simulation Tool

STT – Seaport Throughput Tool

SOUTHCOM – Southern Command

TACC – Tanker Airlift Control Center

TRANSCOM – Transportation Command

TPFDD – Time Phased Force Deployment Data

ULN – Unit Line Number

UN –United Nations

UNAIDS – Joint United Nations Program on HIV/AIDS

USAID – United States Agency for International Development

USTR – United States Trade Representative

Bibliography

-----. *About U.S. Africa Command*. AFRICOM Website. 16 January 2009 www.africom.mil/AboutAFRICOM.asp

Authers, John. "The Short View: African Oil," *Financial Times*, n. pag. April 24, 2007. www.ft.com/cms/s/1/c4040c84-f286-11db-a454-000b5df10621.html

Bosshard, Peter. *China's Role in Financing African Infrastructure*. International Rivers Network, May 2007. www.internationalrivers.org/files/ChinaEximBankAfrica.pdf

Braun, M. D. and Charles VanGroningen. *ELIST 8 Transportation Model*. Argonne, IL.: Argonne National Laboratory, 2 September 2004. http://www.ipd.anl.gov/anlpubs/2002/03/42222.pdf

Castano-Pardo, Alberto and others. *On the Move: Advancing Military Logistics Toward Sense-and-Respond*. IBM Institute for Business Value, 12 December 2006. http://www-935.ibm.com/services/us/gbs/bus/pdf/g510-6558-01-onthemove.pdf

Chairman of the Joint Chiefs of Staff (CJCS). *Joint Logistics.* Publication 4-0. Washington: HQ Joint Staff, 18 July 2008. www.dtic.mil/doctrine/jel/new_pubs/jp4_0.pdf

Chalk, Peter. *The Maritime Dimension of International Security: Terrorism, Piracy, and Challenges for the United States*. Rand Corporation, 2008. www.rand.org/pubs/monographs/2008/RAND_MG697.pdf

Cook, Nicolas. *CRS Report for Congress, AIDS in Africa*. Order Code RL33584. July 27, 2006. 30 December 2008 fpc.state.gov/documents/organization/70321.pdf

Cornella, Al and others. Congressional Report from Commission on Review of Overseas Military Facility Structure of the United States. Arlington, Virginia, 9 May 2005. http://www.fas.org/irp/agency/dod/obc.pdf

Coyle, John J., Edward J. Bardi, and Robert A. Novack. *Transportation* (6th Edition). Mason, Ohio: South-Western Cenage Learning, 2006.

D'Angelo, Dennis L. *Background Paper on Adaptive Logistics Network*. USAFRICOM ADDOC, 28 September 2008.

da Costa, Gilbert. *Regional Infrastructure Tops Agenda at West African Summit*. Voice of America n. pag. 19 December 2008. 31 December 2008 www.voanews.com/english/2008-12-19-voa45.cfm

-----. *Department of Defense Dictionary of Military and Associated Terms*. Joint Publication 1-02. Washington: HQ Joint Staff, 12 April 2001 (Updated through, 17 October 2008).
www.dtic.mil/doctrine/jel/new_pubs/jp1_02.pdf

Diarra, Cheick Sidi. Speech to World Bank, Washington D.C. 22 February 2008.
allafrica.com/stories/200802230006.html

Drabek, Norm. Joint Distribution Process Analysis Center. Personal Correspondence. 24 October 2008 through 4 March 2009.

Drabek, Norm and others. "USEUCOM Airfield Throughput Analysis Study for Strategic Airlift." Report Submitted by USTRANSCOM J5/4-AS. Scott Air Force Base, IL, 6 June 2006.

-----. *Fact sheet: History of U.S. Military Involvement in Africa*. Congressional Research Service, AFRICOM website. n. pag. 16 January 2009
www.africom.mil/getArticle.asp?art=1796

-----. *Fact sheet: United States Africa Command*. US AFRICOM Public Affairs Office, AFRICOM website. n. pag. 25 January 2009
www.africom.mil/getArticle.asp?art=1644

Flanakin, Duggan. *African highway System: Still a Dream?* Committee for a Constructive Tomorrow, n. pag. 5 December 2006. 2 January 2009
www.cfact.org/site/print.asp?idarticle=1141

-----. *How Big is Africa*. Geocities. 19 Jan 2009
www.geocities.com/fon_is_fun/Africa_map_quiz.htm

Jerome, Afeikhena. *Infrastructure in Africa: The Record*. African Development Bank Economic Research Papers #46, 2 May 2004.
www.afdb.org/pls/portal/docs/PAGE/ADB_ADMIN_PG/DOCUMENTS/ECONOMICSANDRESEARCH/ERP-46.PDF

Kansteiner, Walter H., III. and J. Stephen Morrison. *Rising U.S. Stakes in Africa: Seven Proposals to Strengthen U.S.-Africa Policy*. Washington D.C.: Center for Strategic and International Studies Press, 2004.
allafrica.com/sustainable/resources/view/00010230.pdf

Kadivnik, Mike. FEDEX Government Services Worldwide Account Manager. Personal Correspondence. 8 October 2008.

Lake, Anthony and others. *More than Humanitarianism: A Strategic U.S. Approach Toward Africa*. Independent Task Force Report No. 56. New York: Council on

Foreign Relations, Inc., January 2006. 31 December 2008 www.cfr.org/publication/9302/more_than_humanitarianism.html

Lovejoy, Paul. *Transformations in Slavery*. Cambridge: University Press, 2000.

Lyden, Mikael J. *Joint Operational Logistics—Seamless Logistics? View from the Operational Commander*. National Defense Industrial Association 24th Annual National Logistics Conference and Exhibition, 13 March 2008. www.dtic.mil/ndia/2008logistics/Lyden.pdf

McKinzie, Kaye LtCol. and J. Wesley Barnes. "A Review of Strategic Mobility Models Supporting the Defense Transportation System" *Mathematical and Computer Modeling*. Vol. 39, Oxford: Elsevier Science, pp 839-868, 2004. http://www.me.utexas.edu/~barnes/research/files/update_06_2003/RSMMSDTS.pdf

Mutume, Gumisai. "Building an Effective Road Network," *Africa Recovery*, Vol. 16, September 2002, p 23. www.un.org/ecosocdev/geninfo/afrec/vol16no2/162reg4.htm

Nichol, James P. *Analysis of AFRICOM Theater Airlift Distribution Network.* Graduate Research Paper, AFIT/IMO/ENS/08-13. Advanced Study of Air Mobility, Ft. Dix, NJ, June 2008.

PEPFAR Website. *PEPFAR: A Commitment Renewed*. n. pag. 30 December 2008. www.pepfar.gov/documents/organization/107750.pdf

Ploch, Lauren. *CRS Report for Congress, Africa Command: U.S. Strategic Interests and the Role of the U.S. Military in Africa*. Order Code RL34003. Updated August 22, 2008. 22 December 2008 www.fas.org/sgp/crs/natsec/RL34003.pdf

Powell, Stewart M. "Swamp of Terror in the Sahara," *Air Force Magazine*, 87 (11):50-54 (November 2004). 30 December 2008 www.afa.org/magazine/nov2004/1104sahara.html

Ragsdale, Cliff T. *Spreadsheet Modeling & Decision Analysis: A Practical Introduction to Management Science* (5th Edition). Mason, OH: Thomson South-Western, 2007.

Ravindran, A., D. Phillips, and J. Solberg. *Operations Research: Principles and Practices*. Second Edition, John Wiley and Sons, New York, 1987, pp 7-11.

Rising, David. US AFRICOM begins First Peacekeeper Supply Operation. Associated Press Article on U.S Air Force AIM Points Website. n. pag. 15 January 2009. 16 January 2009 http://aimpoints.hq.af.mil/display.cfm?id=31311

Sambu, Zeddy. *East Africa: Countries Move to Upgrade Railway Network*. The Norwegian Council for Africa n. pag. 29 April 2008. 2 January 2009 www.afrika.no/Detailed/16610.html

Schantz, Blair. *AFRICOM Adaptive Logistics Network Concept*. US Africa Command Briefing Slides. 17 Sep 2008.

Simuyemba, Shemmy. Linking Africa Through Regional Infrastructure. African Development Bank Economic Research Paper # 64. 20 May 2004. www.afdb.org/pls/portal/docs/PAGE/ADB_ADMIN_PG/DOCUMENTS/ECONOMICSANDRESEARCH/ERP-64.PDF

-----. Times Online. “Maritime Terrorism: Modern Piracy Finances Extremism. It Must be Shown No Mercy.” *The Times*, n. pag. November 19, 2008. 31 December 2008 www.timesonline.co.uk/tol/comment/leading_article/article5183019.ece

UNAIDS. *2008 Report on the Global AIDS Epidemic: Executive Summary*. Geneva, 2008. data.unaids.org/pub/GlobalReport/2008/JC1511_GR08_ExecutiveSummary_en.pdf

United States Trade Representative. *Report shows AGOA Continues to Grow and Diversify U.S.-Africa Trade*. n. pag. May 16, 2008. 30 December 2008 www.ustr.gov/Document_Library/Press_Releases/2008/May/Report_Shows_AGOA_Continues_to_Grow_Diversify_US-Africa_Trade_printer.html

VanGroningen, Charles. Argonne National Laboratory. Personal Correspondence. 2 February & 27 February 2009.

Venne, Andrew C. HQ 17th AF/A3O. Personal Correspondence. 20 January 2009.

Weiss, John. *Infrastructure and Economic Development*. African Development Bank Economic Research Papers #50, 6 May 2004. www.afdb.org/pls/portal/docs/PAGE/ADB_ADMIN_PG/DOCUMENTS/ECONOMICSANDRESEARCH/ERP-50.PDF

Appendix A. EUCOM Airfield Throughput Executive Summary

Appendix B. APOD Output for Dakar, Senegal (GOOY)

Appendix C. APOD Output for Entebbe, Uganda (HUEN)

Appendix D. APOD Output for Mombasa, Kenya (HKMO)

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14. ABSTRACT
Since the 1990s, Africa has grown in strategic importance to the United States due to oil, trade, armed conflict, terrorism, and HIV/AIDS. As a result, the United States created Africa Command (AFRICOM), a new military geographic combatant command. AFRICOM's mission is to aid African development and promote regional security. As part of its mission, AFRICOM will need to move cargo throughout Africa, which has the least developed transportation infrastructure in the world. Coupled with the poor infrastructure issue, AFRICOM only has one base on the continent and extremely limited dedicated transport assets. AFRICOM logistics planners' solution to this problem is the creation of an Adaptive Logistics Network (ALN) that can expand or contract as necessary using in place transportation assets owned by African businesses. However, logistics planners still must know how much cargo can be pushed through individual airports, and once there, how far that cargo can be moved in a given amount of time. Two mobility modeling simulations, the Airport Simulation Tool (AST) and the Enhanced Logistics Intra-theater Support Tool (ELIST), are detailed by this study showing how they can assist in estimating the answers to how much and how far. The models' capabilities and limitations are explored, and recommendations are made to assist AFRICOM in the use of these two tools to aid AFRICOM logistics planning and forecasting.

15. SUBJECT TERMS
AFRICOM, Adaptive Logistics Network, African Infrastructure, Cooperative Security Location, Dakar, Senegal, Mombasa, Kenya, Entebbe, Uganda, APOD, ELIST

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